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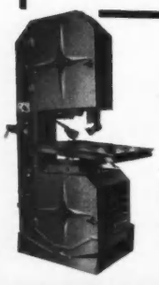

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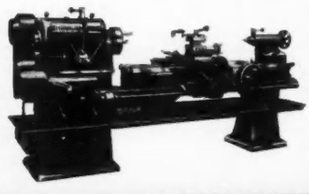

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THE BRITISH INDUSTRIES FAIR AT BIRMINGHAM—III.

THIS year, at Castle Bromwich in Birmingham and at Earls Court and Olympia in London, the general public have been admitted to the Fair every afternoon and all day on Saturday. The staff on duty at the 2,000 stands may have good cause to feel, when the Fair closes to-day, that this decision was not in their interests, but there can be no doubt that it was a sound decision; British industries gain as much, in the long run, from the goodwill, interest and understanding of those who have no official reason for visiting the Fair as from those who have. The Fair is intended to serve home buyers as well as buyers from overseas, but special importance attached to the latter category this year. The number of acceptances from overseas buyers invited personally by the Board of Trade was 35 per cent. more than the number last year.

At Castle Bromwich, there are approximately 1,250 exhibitors, mainly in heavy industry. Some further items of engineering interest are described below, starting with two items which it has not been practicable to illustrate—factory swing doors with rubber panels, and V-belts and pulleys.

BELTING AND PULLEYS.

Messrs. J. H. Fenner and Company, Limited, Hull, are showing a new range of V-belts in which the load-carrying cords are made from high-strength-filament rayon, giving the belt a greater tensile strength and a higher power capacity than has hitherto been possible, a higher modulus (i.e., load for a given stretch), and greater resilience and resistance to shock loads. The heat resistance is improved, and it is claimed that under difficult conditions these belts have a longer life. They are also demonstrating a new length-coding system for selecting V-belts to run as matched sets. A new Taper-Lock pulley, $\frac{3}{8}$ in. wide, is on view; hitherto, Taper-Lock pulleys have been available only with $\frac{1}{2}$-in. and $\frac{21}{32}$-in. grooves. Briefly, the Taper-Lock pulley consists of a tapered bush forced by screws threaded in the pulley into the taper-bored hub, thus forming a wedge which holds the pulley in engagement with the shaft.

The Fenner company are also showing flame-resistant conveyor belting, Fenaplast, for use in collieries. It consists of a solid-woven belt, with strengthened selvedges, thoroughly impregnated with polyvinyl chloride, and is available in widths up to 30 in. Fenaplast, which has been officially approved by the National Coal Board, is claimed to have an unusually high gripping power, which reduces the driving tension and the load on the bearings, and is resistant to wet, dirty and abrasive conditions.

RUBBER SWING DOORS.

A working model of factory swing doors with rubber panels is being shown by the Dunlop Rubber Company, Limited, Fort Dunlop, Birmingham, with a truck passing through them. When a truck is driven straight at these doors, they open easily without noise, no damage being done to the doors, the truck, or its load. They are of the normal swing type with either one or two panels, swinging one or both ways as required. The frame is made of tubular steel in an inverted "L" shape, and the two parts are braced together by a triangular plate. The vertical tube fits close to the door frame and turns at the top and bottom on pivots let in the lintel and the floor. The return spring is totally enclosed in the top of this vertical tube. The horizontal portion of the frame acts as a support for the rubber panelling which is securely bolted to it and also to the vertical post. The panelling is made of canvas-reinforced rubber sheeting with a standard thickness of $\frac{1}{16}$ in. The canvas reinforcement is of heavy duck, and the rubber face on each side, of a very tough hard-wearing quality, has a thickness of $\frac{1}{16}$ in. The panels overlap at the centre by about 1 in. and prevent draughts. Let into each panel is a rectangular observation window made from Perspex; it is set at an angle to allow people of different height to look through without difficulty, and is so placed that the rubber panelling will not be distorted by its rigidity when the door is opened. Black is the normal colour of these doors but a drab rubber covering can be obtained which is ideal for use in dairies, canteens and hospitals. The total weight is less than that of an ordinary wooden swing door, so that it can be opened without any difficulty. Hands cannot be hurt if accidentally trapped between the panels, and no handles need be fitted as the doors can be easily opened by slipping a hand between them. They have been developed as a result of co-operation between the Dunlop Company and William Newman and Sons, Limited, Birmingham, 19, who are responsible for marketing the doors through their agents and builders' merchants.

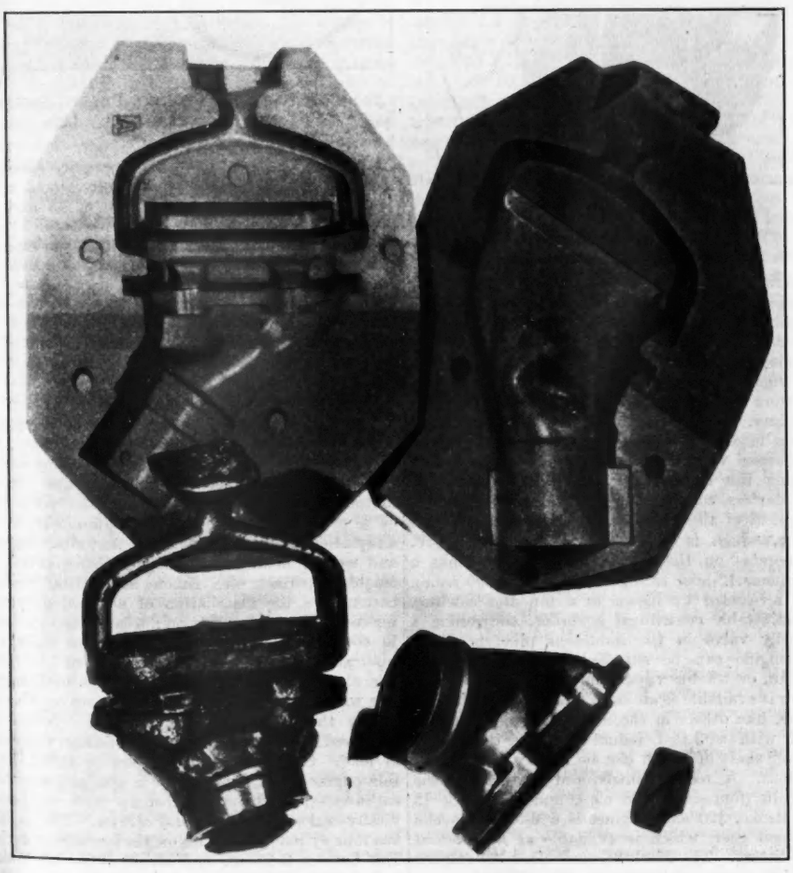


FIG. 31. FOUNDRY MOULDS FROM SYNTHETIC RESINS; BAKELITE LTD.

FOUNDRY MOULDS FROM SYNTHETIC RESINS.

The exhibits of Messrs. Bakelite Limited, 12-18, Grosvenor-gardens, London, S.W.1, illustrate the wide range of plastic materials manufactured by them, and the diversity of their applications. The materials on view include Bakelite phenolic and urea resins and moulding materials, laminated sheet, rod and tube and Vybak thermoplastic compounds for extrusion and injection moulding, and soft and rigid calendered sheet. Warerite decorative laminates for wall panelling and furniture are also on view. Among the finished products is a high-alloy steel aircraft casting, by Messrs. Rolls-Royce, Limited, Derby, illustrated in Fig. 31, which was produced from a shell mould made from a Bakelite resin. Several different grades of resin are now available for the new shell-moulding process. The Bakelite company have also developed various improvements in the process, including a means for bonding half-moulds together, thus eliminating the need for clips.

Examples of the new group of polyester resins are also on view. These resins can be cured without the liberation of water, so they can be used for low-pressure laminating and moulding much larger structures than has hitherto been economically feasible. They are widely used in combination with glass fabric for applications such as boat structures, corrugated roof-glazing, fishing rods and aircraft components. The polyester resins are suitable for casting, which, combined with their transparency and electrical properties, render them suitable for embedding scientific specimens and for enclosing delicate components such as miniature radio circuits. Three grades of laminated glass, based respectively on phenolic, silicone and melamine resins, are also on view; these materials, heat-resistant, mechanically strong, and retaining their electrical properties at high temperatures, are used in the electronics industry. In the range of mould-

EXHIBITS AT THE BRITISH INDUSTRIES FAIR.

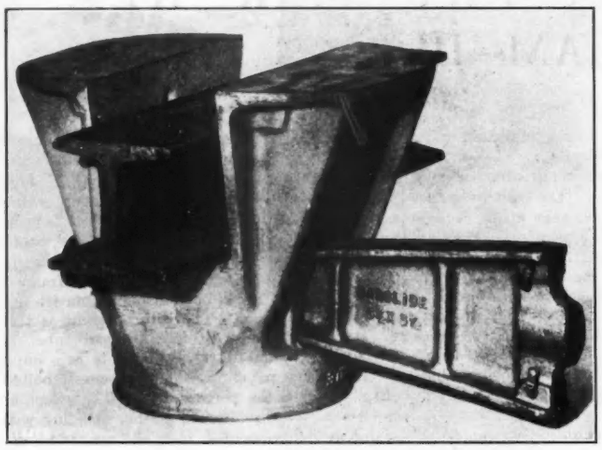


FIG. 32.

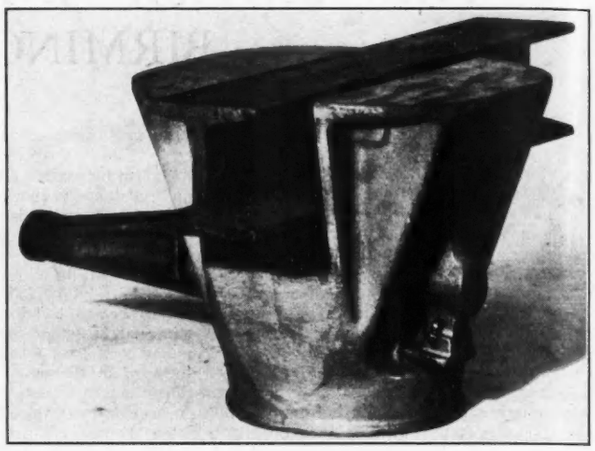


FIG. 33.

FIGS. 32 AND 33. "BARSLIDE" HEAD FOR PIT PROPS; HALE & HALE (TIPTON), LTD.

ing compounds, rubber is being used as a fibre for both phenolic and polystyrene materials, giving improved shock resistance. New alkyd moulding materials combine attractive colouring with good resistance to heat and outstanding electrical properties.

"BARSLIDE" HEAD FOR PIT PROPS.

The "Barslide" pit-prop head, made by Hale and Hale (Tipton), Limited, Tipton, Staffordshire, has been developed from a device introduced by Mr. N. R. Smith, area production manager of the East Midlands Division, National Coal Board. The Barslide is intended for use with pit props, preferably of the Dowty hydraulic type, and affords means of giving support to a roof between, and in advance of, the props. By its use, the roof supports can be moved forward without removing the props, or even taking the weight off them.

It consists of a pair of blackheart malleable-iron castings, one being socketed to fit on the head of the pit prop, and the other being wedge-shaped to support, adjustably, a rolled-steel joist. Fig. 32, on this page, shows the Barslide with the wedge set in its lowest position, and Fig. 33 illustrates it with the wedge fully raised. The Barslide rests on the top of the Dowty hydraulic prop, and as the prop is tightened the top flanges of the head support the roof in the normal way. A steel joist is inserted in the slot in the top of the Barslide, and extends to the next prop or props. The joist can then be tightened against the roof by means of the wedges. When it is necessary to move the joist forward, to support an advancing roof, the wedges are lowered about 1½ in. by striking them with a hammer. The joist is then free to slide. It is moved to its new position, and tightened against the roof by driving the wedges in. During the operation of moving the joist, the Barslide head has continued to give the normal support to the roof. The unit can be fitted with two small pawls, by which it hangs on the joist when the prop is removed. A prop can thus be withdrawn, and re-set elsewhere, without disturbing the Barslide, which can be slid along the joist to meet the prop in its new position. The pawls can be disengaged easily with the fingers if it is desired to remove the head from the joist after the prop has been withdrawn. The head is 10 in. high, and has a maximum lift of about 2 in.

LIGHTWEIGHT PETROL ENGINES.

The Villiers Engineering Company, Limited, Marston-road, Wolverhampton, are showing the complete range of their stationary, two-stroke and four-stroke, air-cooled petrol engines, from ½ h.p. to 5 h.p., and examples of their lightweight engines for building into motor-cycles, agricultural implements, mowing machines, etc. The range includes both horizontal and vertical engines. The sets of tools specially developed by the company for servicing their engines are also shown, and there is a display of free-wheels and chain sprockets for vehicles and industrial use. The engines incorporate the company's design of flywheel magneto, which can also be used as a lighting-set generator when the engine is fitted to a motor-cycle. The carburettors are also designed and made by the Villiers Company. A vaporiser is available for fitting to certain models, to enable them to run on paraffin or tractor vaporising oil. Various methods of starting the engines are shown. These include kick-starters, cord and drum, and electric starters.

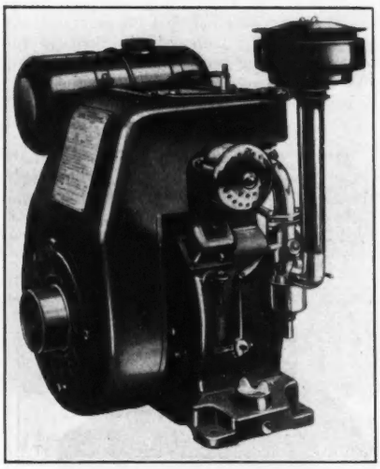


FIG. 34. 4-H.P. AIR-COOLED ENGINE; VILLIERS ENGINEERING CO., LTD.

Typical of the industrial range is the Mark 40 engine, which is illustrated in Fig. 34, above. It operates on the four-stroke cycle and has a continuous 12-hour rating of 4 h.p. at 2,000 r.p.m. It is air-cooled by means of a fan and cowling. An adjustable centrifugal governor, controlling a butterfly valve in the induction pipe, is fitted. The engine can be supplied to run on petrol, paraffin, or tractor vaporising oil, and an electric starter is available as an extra fitment. The Mark 40 engine, like others in the industrial range, can be fitted with a 3-to-1 reduction gear, the power take-off shaft of which can be in any one of four positions. A recently-introduced feature on the Mark 10 (four-stroke, 98 c.c.), and the Mark 12 (four-stroke, 120 c.c.) engines is a 6-to-1 epicyclic reduction gear, which is available as a standard extra fitting. The Mark 2G and Mark 3G engines are also recent additions to the Villiers range. The Mark 2G engine (Fig. 35, herewith) is a horizontal air-cooled two-stroke engine, specially designed for powering small cultivators, hoes, lawn-mowers, etc. It has a bore of 43 mm., a stroke of 48 mm., and a cubic capacity of 70 c.c. It is equipped with the normal Villiers carburettor and flywheel magneto. The normal power take-off is a 12-tooth ½-in.-pitch chain sprocket. The Mark 3G engine is basically the same as the Mark 2G, the size and rating being identical in both engines. The Mark 3G is, however, fan-cooled, with a flywheel fan and cowling.

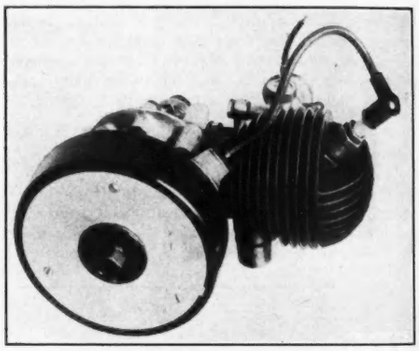


FIG. 35. 70-C.C. HORIZONTAL PETROL ENGINE; VILLIERS ENGINEERING CO., LTD.

800-C.C. 4-CYLINDER INDUSTRIAL ENGINE.

The Newage-Austin 800-c.c. industrial engine shown in Fig. 36, opposite, is being exhibited by Newage (Manchester), Limited, Crossley-street, Manchester, 18, in conjunction with the Austin Motor Company, Limited, and is the prototype of a new range of industrial engines. It is an adaptation of the Austin Seven motor-car engine, and will be made for running on either petrol or tractor vaporising oil. Among some of the modifications are the installation of a speed governor for constant-speed operation; a larger fan to assist in cooling; a magneto; and, in some cases, an up-draught carburretor. The standard flywheel and clutch-housing is replaced by one of a larger size which can be adapted for gearboxes capable of giving the desired output, and the flywheel is increased in diameter to absorb any sudden variation of load. Other features that can be included in this engine when required are a special dust-proof carburettor, distributor, oil-sump filler cap, and totally-enclosed dynamo and starter. The engine has four cylinders and runs on the four-stroke cycle. The bore is 2·28 in. and stroke 3 in. A brake horse-power of 30 is reached at 4,800 r.p.m. and the maximum torque is 40 lb.-ft. at 2,400 r.p.m.,

THE BRITISH INDUSTRIES FAIR.

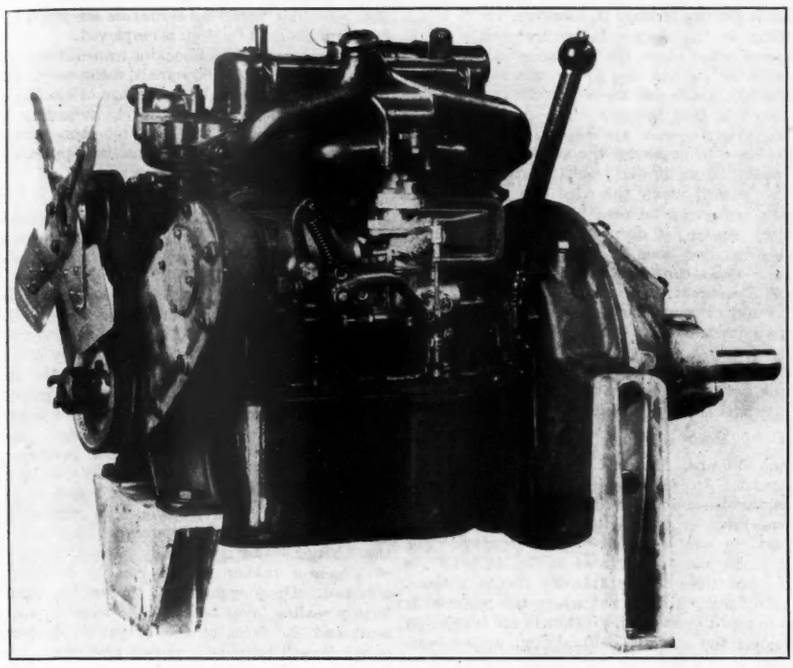


FIG. 36. 800-C.C. 4-CYLINDER INDUSTRIAL ENGINE; NEWAGE (MANCHESTER), LTD.

with a fuel consumption of approximately 0·6 pint per brake horse-power per hour. The compression ratio is 7·2 to 1. The overhead valves are push-rod operated. The lubrication is from a rotor-type pump which gives a pressure of 50 lb. to 55 lb. per square inch when the engine is warm. The fuel system incorporates a mechanical-type pump made by AC-Sphinx Spark Plug Company, Dunstable, and the fuel tank provided with the engine has a capacity of 5¾ gallons. The cooling water is circulated by a centrifugal pump and a thermostat is placed in the circuit to assist in maintaining the engine temperature at 164 deg. F.

VICKERS TRACTOR WITH CABLE DOZER.

On the stand of Jack Olding and Company, Limited, Hatfield, is a large variety of road-making and levelling equipment, most of which is based on the Vickers VR180 tractor, powered by a Rolls-Royce supercharged six-cylinder engine. The tractor is shown in Fig. 37, on Plate XVI, fitted with a VUCD180 cable dozer, being used for the stock-piling of coal at Nine Elms Gas Works of the North Thames Gas Board, Battersea. The fully-articulated suspension and reflexing track, it is claimed, facilitate the use of high operating speeds to give an increase rate of piling. A clear view is provided for the operator and all the controls are placed within a convenient distance of the driving seat. The cables for adjustment of the dozer-blade setting are carried through a tubular beam, mounted above the tractor on two inverted U-shape brackets, and run over pulley wheels at each end. The winding drums for the cable are placed at the rear of the tractor and driven through gears. The engine gives 150 drawbar horse-power and runs at a governed speed of 1,800 r.p.m. There are six forward gears and three reverse gears. The maximum forward speed is 9·73 m.p.h.

MOBILE DIESEL ALTERNATOR SET.

Houchin, Limited, Garford-street, London, E.14, exhibit the mobile Diesel alternator set shown in Fig. 38, on Plate XVI. The output of the alternator is 93 kW, 116·2 kVA at a power factor of 0·8, and it is wound for 400/440 volts, 3 phase, 50 cycles, 4 wire. It is a salient-pole single-bearing type of alternator, with a frame size of BH3/100 and a four-pole stator arranged for flange mounting to the Diesel engine flywheel housing. The rotor, which is dynamically balanced, is coupled by a flange directly to the engine flywheel and runs in a heavy-duty journal with a double-row type of bearing. Grease lubrication is used. The Diesel engine is made by W. H. Dorman and Company, Limited, Stafford, and is their type 6KA engine. At a 12-hour rating it gives an output of 145 brake horse-power at 1,500 r.p.m. There are six cylinders of 135-mm. bore and 160-mm. stroke. The fuel system uses the direct-injection type of C.A.V. equipment, and a 24-volt starter motor is fitted as standard equipment. Both the engine and the alternator are mounted on a base fabricated from steel sections. Mounted forward of the engine is the radiator for the engine-cooling water. At the other end, directly above the alternator, is the instrument panel with the controls and switchgear. The fuel tank, which has a capacity of 36 gallons, is installed over the rear end of the engine and is complete with filler and indicator gauge. Both the engine and alternator are mounted directly on to a chassis fitted with spring suspension, hub brakes, and heavy-duty tyres. The front axle is attached to a plate which revolves about a centre point to assist in the steering of the trailer, and a steel drawbar is attached to the ends of the axle. Pillars at the side of the frame support a sheet-steel cover above the engine and the alternator for weather protection, and canvas curtains, which can be rolled up, are hung around three of the sides, the radiator end being excluded. The exhaust pipe passes out through the top cover.

1-OZ. INJECTION MOULDING MACHINE.

The new Windsor 1-oz. automatic injection moulding machine illustrated in Fig. 39, on Plate XVI, is being shown by R. H. Windsor, Limited, Chessington, Surrey. It is the smallest of the Windsor range of injection moulding machines and has been designed to meet the needs of producers of a variety of both small and large mouldings for rapid and reliable operation. The injection plunger normally operates at 20,000 lb. per square inch when producing 1-oz. mouldings, but with the aid of an additional liner and plunger 2-oz. mouldings can also be produced at a pressure of 13,000 lb. per square inch. Its plasticising capacity varies between 22 and 24 lb. per hour, and on a dry run it has a maximum output of 480 shots an hour. During tests it gave six shots a minute at full weight. The machine is fully automatic when running, thereby enabling one operator to attend a number of machines. The control gear, which is completely mechanical, can be set for operation on either a fully-automatic or a semi-automatic cycle. There is a direct hydraulic locking pressure of 30 tons, and the injection mechanism is interlocked with the locking clamp to ensure that injection does not take place before the moulds are positively locked together. The design is based on the Windsor retraction system, which gives ease of access to the sprue-bush and material cylinder. When it is required to break the sprue the retraction unit can be actuated to the required amount at each stroke. The main parts of the locking and injection units and the mould plates are made from Meehanite iron and heat-treated. All the hydraulic pistons used are fitted with piston rings so as to give longer life. The hydraulic power is supplied by a Vickers vane-type double pump coupled to a 7½-h.p. electric motor.

All the equipment is mounted on a stool and bolted to the base frame, which is of welded steel construction. The lower part of the base frame acts as a reservoir for the hydraulic fluid. The diameter of the injection plunger is 1$\frac{11}{16}$ in. and its area is 1·42 sq. in.; it carries a load of 28,275 lb. The stroke is 5 in. and the plunger speed is 195 in. per minute. The actual time taken for injection is 1·62 seconds. The size of the mould plates is 16 in. by 11¼ in., with a maximum area moulded of 10 to 15 sq. in., and the hopper has a capacity of 440 cub. in. The controls are placed at the front of the machine and a pyrometer gives the temperature of the plasticised material, which is automatically measured and fed from the hopper. Electric beds provide the heat for plasticising, and a gauge is fitted to show the hydraulic pressure of the system. The finished parts are ejected down a chute in the front of the base frame, directly beneath the moulding dies.

AUTOMATIC OIL BURNER.

A range of oil burners suitable for various grades of fuel oils and distillates is exhibited by Prior Stokers, Limited, Brandon-road, York-way, London, N.7. The Prior pressure burner illustrated in Fig. 40, on Plate XVI, is being shown for the first time, and is designed for use with distillate oils, such as gas or Diesel, with a viscosity of 30/70 seconds Redwood No. 1 at 100 deg. F.; this jet-type burner is fully automatic and is suitable for hot-water installations and steam boilers rated at from 100,000 to 300,000 B.Th.U.'s an hour. The burner incorporates a patented flame-stabilisation device, which ensures thorough mixing of the fuel and air consumed, resulting in a high efficiency of operation and the utmost cleanliness of combustion.

"EUCLID" BOTTOM-DUMP WAGON.

Messrs. John Blackwood Hodge and Company, Limited, 11, Berkeley-street, London, W.1, are showing a large range of equipment for contractors and civil engineers at home and overseas. This equipment is now built in Great Britain, thereby eliminating currency difficulties. It includes the Carlisle grader, Carlisle angle-dozing equipment for Caterpillar tractors, a Euclid tractor and scraper unit, Euclid rear-dump wagons, and the Euclid bottom-dump wagon, which is now being made at Euclid's Newhouse (Glasgow) works and is exhibited for the first time. It is illustrated in Fig. 41, on Plate XVII.

The bottom-dump wagon is an articulated vehicle consisting of a tractor and pivoted trailer. Its struck capacity is 13 cub. yards and the heaped load, assuming a 1 in 3 slope, is 15·1 cub. yards. The payload is 40,000 lb. and the turning radius is 42 ft., or 35 ft. with steering brakes. The trailer consists of a drawbar, hopper, centre partition, axle brackets, doors, door-operating mechanism, etc. The hopper is of welded construction, with stiffened $\frac{7}{16}$-in. side plates and $\frac{3}{8}$-in. front and rear plates. The centre partition is a welded box member, bolted through side plates to outer stiffening channels. The main door plate is of ½-in. steel plate, reinforced by channels and bars. A continuous cable, $\frac{3}{16}$ in. in diameter, is fitted to the trailer. The door operating mechanism is controlled by an air valve on the steering column, the cable-

drum lock being released to open the doors, and the winding mechanism being engaged to close the doors.

The wagon tractor is fitted with a Leyland 11·1-litre 154-h.p. engine and a five-speed gearbox. The driving axle is of the Euclid heavy-duty type, with a fully-floating double-reduction drive. Service brakes, air-pressure operated, are provided on the rear wheels of the tractor and trailer, and there is also a disc-type hand-operated emergency brake acting on the propeller shaft. The main performance data for the complete rear-dump wagon are as follow: coefficient of friction between the tyres and the ground, 0·6; rolling resistance, 40 lb. per ton; and the mechanical efficiency, engine to ground, 85 per cent. In first gear the wagon will climb a 23 per cent. gradient loaded or a 21 per cent. gradient empty.

HEAVY-DUTY FORK-LIFT TRUCK.

One of the exhibits on the stand of I.T.D., Limited, 95-99, Ladbroke-grove, London, W.11, is the "Stacatruc" model No. 45 EH/9. It is a heavy-duty fork-lift truck of the battery-electric type, and is illustrated in Fig. 42, on Plate XVII. The maximum lift is 9 ft., and the maximum loading on 20-in. centres is 4,500 lb., and 4,000 lb. on 24-in. centres. It is constructed around a chassis frame of exceptional rigidity, the driving axle mounted at the forward end, together with the lifting mast and forks. At the rear of the chassis is a cast balance weight and guard block designed to act as a fender for the full height of the body. Carried above and to the rear of the chassis is the battery, housed in two sections for easy removal by a block and tackle. It is protected by a smooth steel cover-plate. The forward end of the chassis accommodates the hydraulic oil tank, the driving seat, hydraulic control levers and operating pedals. The driving footplate is made removable to allow inspection of the electrical control gear and hydraulic mechanisms mounted beneath it. At each side of the main frame is a pannier compartment; in the right-hand compartment is the hydraulic pump and motor assembly, and in the left-hand the electrical driving-control unit. Both these assemblies hinge outwards to provide full accessibility. Four road wheels are fitted. The steering axle is fitted with semi-elliptic springs carried on an axially-pivoted frame to ride freely over surface irregularities without imparting side roll to the truck. It is claimed that the advantage of this system of suspension is that the forced rise or fall of either of the steering road wheels only produces a vertical displacement on the truck of half the wheel displacement.

PRECISION SQUARE.

The Acru Electric Tool Manufacturing Company, Limited, Chapel-street, Levenshulme, Manchester, 19, are showing a new engineer's precision square and a master square.

The precision square, which is shown in Fig. 43, on Plate XVII, is designed for testing the angles between finished plane surfaces, and enables the angular error to be read directly in units of 0·001 in. per foot by means of a dial gauge incorporated in the square. Up to the present, engineers' squares have consisted mainly of a relatively heavy base member on one end of which is formed a slot, and a blade is inserted rigidly therein and set accurately to 90 deg. To find the angular error the square is placed on the article to be measured and feeler gauges placed in between the blade of the square and the plane surface of the article. The thickness of the feeler which can be inserted in the gap gives an indication of the angular error. The new square has a pivoted blade which is angularly movable relative to the base to vary the included angle; it has means for indicating a true right-angle and the extent, as well as the sense, of departure therefrom. The blade can be clamped at the pivot to enable the frictional resistance to pivotal movement to be adjusted. Attached to the blade, and extending within and along the centre-line of the base, is a long finger in engagement with the feeler element of a dial indicator mounted on the side of the base. A return spring is connected to move the blade to the minus or acute side of a true angle. The dial is conveniently rotatable for setting to zero. The indicator and lever are so proportioned that one division of the dial represents 0·001 in. of error per foot. The dial is calibrated to indicate up to ±0·030 in. error per foot. The scale can be fixed with a screw so that the pointer is at zero when the square is exactly 90 deg. If, however, due to rough handling or the square being dropped, a slight distortion takes place, the zero point can easily be adjusted by putting the square against a known true 90-deg. angle and the scale then re-set to zero and fixed in that position. The advantages over ordinary rigid squares are stated to be: no feeler gauges have to be used; the angular error can be read exactly from the dial; on large areas the square can be pushed along the edge and the different angular errors can be read immediately; and an ordinary square, if dropped on a hard floor or roughly handled, soon loses its accuracy, whereas the new square can always be re-set to the highest degree of accuracy.

The firm's master square has a precision-ground base, and instead of a square blade there are two tungsten-tipped screw heads set to give an exact 90-deg. angle. This master square is inexpensive because only one angle has to be ground and the second angle is provided by the set-screws.

PUMP FOR DRY MATERIALS.

Mono Pumps, Limited, 67, Clerkenwell-road, London, E.C.1, exhibit a new pump for handling dry materials such as powders; development work is proceeding, in conjunction with Henry Simon, Limited, to enable cereals to be handled. The DM12 Mono pump, illustrated in Fig. 44, on Plate XVII, will fulfil simple transfer duties without the aid of air injection, but where the material is to be pumped over greater distances air is injected to fluidise the material. Fluidising, applications of which have been described in ENGINEERING on several occasions recently (notably in connection with the handling of powdered peat in a Ruston and Hornsby gas turbine), requires only a comparatively slight flow of air; its purpose is simply to provide a blanket of air round all the particles and thus reduce friction, and also, in the case of the Mono pump, to prevent a high build-up of pressure along the discharge line.

An experimental installation of a Mono DM12 pump gave the following results (which should not be taken as representative or factual for all conditions): with a 90-ft. circuit of 3-in. piping, including a vertical length of 25 ft., the pump handled 7 to 8 tons per hour (450-520 cub. ft.) of powder weighing 35 lb. per cubic foot; the suction was "flooded," and, on the discharge side of the pump, air injected at a pressure of about 5 lb. per square inch at 10 cub. ft. per minute was sufficient to keep the powder in a fluidised condition. The DM12 pump at the British Industries Fair is demonstrated by drawing powder from a hopper and lifting the material back to the hopper. This demonstration represents a most economical form of conveyance for such simple installations. The intake and output are uniform and therefore steady quantities of powder progress through the pipeline at the same rate of flow. This steady rate of flow is the great advantage offered by the pump. The assistance from injected air is kept within very low limits and an economy in equipment and in power is achieved as compared with the blowing of powders by compressed air. The application of the Mono pump to this duty is in its early stages and research is being carried out to widen its scope in this field.

"UNDERDOME" BELL.

Messrs. Gent and Company, Limited, Faraday Works, Leicester, are showing a range of domestic and industrial bells, among which is a new type of underdome bell for industrial use, shown in Fig. 45, on Plate XVII. It has an 8-in. diameter cast-steel gong, enclosing all the working parts and ensuring considerable protection against the weather. An unusual feature is that the hammer shaft has been designed to hit directly the under-cage of the gong. Three types of bell are available, for battery operation, for alternating-current mains, or for direct-current mains for all voltages up to 250 volts. A special model is available for the Canadian market. All types of underdome bell are drilled for conduit entry at the top, bottom, sides, and rear, those for the English market to take ¾ in. threads and those for the Canadian market ½ in. threads. A separate back plate is available for accommodating flush-type conduit boxes. Robust and accessible protected terminals are fitted in the base. Bakelite insulation is employed.

Also on view is a staff locator transmitter capable of transmitting up to 63 signals, using only six keys and three coloured lights; a range of clocks; fire-alarm equipment; liquid-level indicating and recording equipment; internal telephone systems; burglar alarms; and mine-signalling apparatus.

BONDED-RUBBER SEAL.

Being exhibited for the first time are examples of the many interesting and ingenious high-pressure sealing devices produced by Dowty Seals, Limited, Ashchurch, Gloucestershire. One of these is the "Dowty Bonded Seal," which can be used wherever a washer is required to act also as a seal. By a patented bonding process, a rubber sealing ring of specially-designed section is permanently attached to a metal washer. When tightened, the flared edges of the rubber sealing ring are depressed to form a sealing annulus providing a perfect leakproof joint capable of withstanding pressures up to 10,000 lb. per square inch. These washers are available in a wide range of standard sizes and are suitable for use with acids, alkalis, liquids or gases.

By the same bonding process, an efficient leak-proof bolt has also been produced. It is known as the "Strud," and is basically a countersunk bolt to which a rubber sealing ring is permanently attached. Upon tightening, the rubber flows to form a sealing layer between the countersunk bolt head and the faces of the prepared countersunk hole. It will provide a simple and efficient leak-proof fixing for use in the fabrication of pressure vessels. Many of these bolts have been used in the construction of the integral wing fuel tanks on the de Havilland Comet jet airliner. The Dowty sealing lock washer was described on page 547, *ante*.

ROTARY SHEARING MACHINE.

The Scottish Machine Tool Corporation, Limited, 124, Vincent-street, Glasgow, C.2, are exhibiting, in addition to a 200-ton press described in last week's issue, the Craig and Donald rotary shearing machine with a twin-motor drive, which is capable of shearing mild-steel plate up to ¼ in. in thickness. The main frame of the machine is a heavy box-section casting and housed within it are two electric motors for driving the cutters. For access to these motors, inspection plates are fitted. The gap is 36 in. and the saddle carrying the top cutter is adjustable by means of a hand-wheel. The spindles carrying the top and bottom cutters are both driven through gears, which are cut from high-carbon steel, by individual motors using three-phase 400-volt 50-cycle supply. The cutters have two running speeds, 4 ft. per minute, and 8 ft. per minute, and push-button controls are fitted.

(To be continued.)

SYMPOSIUM ON AERONAUTICAL ACOUSTICS.—An all-day meeting has been arranged by the Royal Aeronautical Society and the Acoustics Group of the Physical Society on "Aeronautical Acoustics: In Particular Jet Noise," and will be held on Thursday, May 21, at the Institution of Mechanical Engineers, Storey's-gate, St. James's Park, London, S.W.1. At the first session of the meeting, from 10 a.m. to 11.30 a.m., two papers on "Engine Noise" will be read by Professor E. J. Richards and Mr. F. B. Greatrex, respectively. The second session, from 11.30 a.m. to 1 p.m., will deal with "Aircraft Noise," and papers will be read on "Aerodynamic Noise" by Mr. G. M. Lilley, and on "Noise Associated with Supersonic Flight" by Mr. C. H. E. Warren. After an interval for lunch, there will be a session, from 2.30 p.m. to 4 p.m., on "Ground Noise," at which papers will be read on "Air-to-Ground Noise" by Mr. N. Fleming, and on "Ground-to-Ground Noise" by Mr. J. D. Hayhurst. There will be an interval for tea, after which a general discussion covering the whole meeting will take place. This is timed to commence at 4.30 p.m. and to finish at about 6 p.m. Programmes and additional information may be obtained from the secretary of the Royal Aeronautical Society, 4, Hamilton-place, London, W.1, or the secretary of the Physical Society, 1, Lowther-gardens, Prince Consort-road, London, S.W.7.

(To face page 580.)

EXHIBITS AT THE BRITISH INDUSTRIES FAIR.

(*For Description, see Page* 577.)

FIG. 37. VICKERS TRACTOR WITH CABLE DOZER; JACK OLDING & CO., LTD.

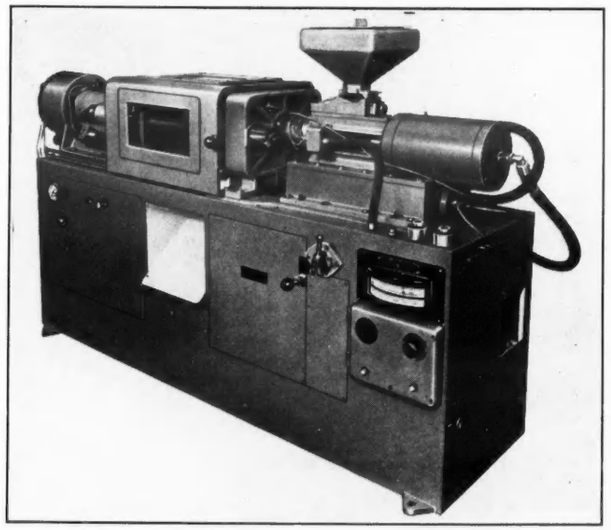


FIG. 39. 1-OZ. INJECTION MOULDING MACHINE; R. H. WINDSOR, LTD.

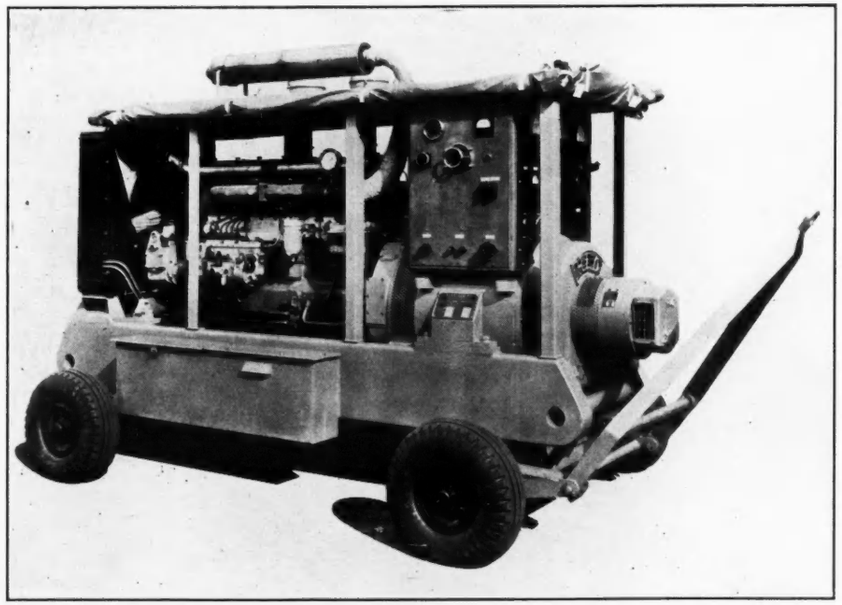


FIG. 38. MOBILE DIESEL ALTERNATOR SET; HOUCHIN, LTD.

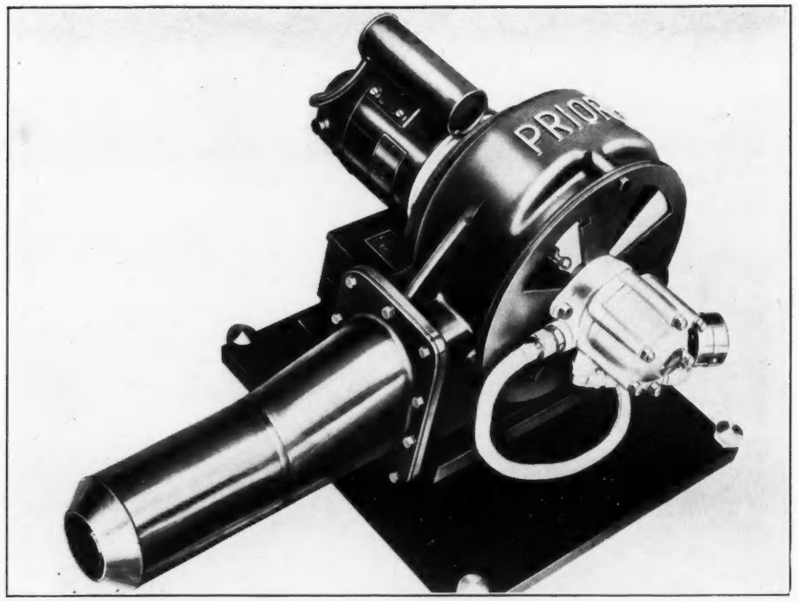


FIG. 40. AUTOMATIC OIL BURNER; PRIOR STOKERS, LTD.

EXHIBITS AT THE BRITISH INDUSTRIES FAIR.

(*For Description, see Page 577.*)

FIG. 41. "EUCLID" BOTTOM-DUMP WAGON; JOHN BLACKWOOD HODGE & CO., LTD.

FIG. 42. HEAVY-DUTY FORK-LIFT TRUCK; I.T.D., LTD.

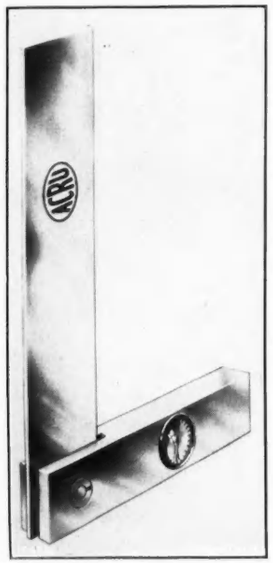


FIG. 43. PRECISION SQUARE; ACRU ELECTRIC TOOL MFG. CO., LTD.

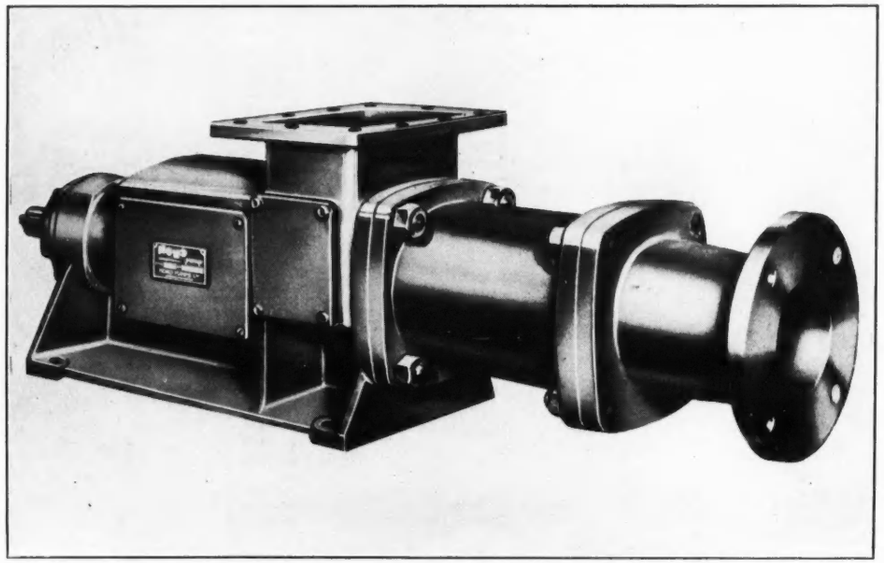


FIG. 44. PUMP FOR HANDLING DRY MATERIALS; MONO PUMPS, LTD.

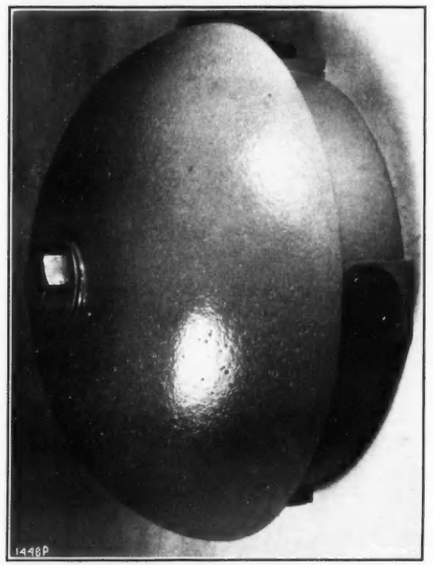


FIG. 45. "UNDERDOME" BELL; GENT & CO., LTD.

(*To face page* 581.)

LITERATURE.

An Introduction to Scientific Research.

By PROFESSOR E. BRIGHT WILSON, Jr., McGraw-Hill Book Company Incorporated, 330, West 42nd-street, New York 36, U.S.A. [Price 6 dols.]; and McGraw-Hill Publishing Company, Limited, 95, Farringdon-street, London, E.C.4. [Price 51s.]

THE outstanding scientists, of to-day no less than of the past, embrace within their genius certain innate, individual qualities that can hardly be analysed, much less taught to others. But in addition to the natural gifts which prompted them to search in such directions as ultimately led to important discoveries, they cultivated in themselves, and often left on record in their writings, methods of thought and experimental practice that can be acquired and used with advantage by the more pedestrian majority of the great army of workers nowadays engaged in scientific and industrial research.

The author of this book, who is a Professor of Chemistry at Harvard University, has evidently undergone a deal of searching interrogation on such matters by students intending to make a career in research, and has come to the conclusion that the generally accepted ideas on the subject are worth collecting together and presenting in an orderly manner with adequate explanations and examples. The outcome is a readable, well-annotated introduction to the practice of research which experienced workers no less than beginners will study with advantage.

The early chapters on such elementary matters as defining the nature of a research problem, searching the relevant literature and designing appropriate experiments and apparatus all embody, for instance, suggestions and ideas that are too often neglected by experimenters who do not instinctively appreciate their importance. The wider possibilities of experimental economy in the attainment of conclusive results are examined in subsequent chapters which the author devotes to a variety of statistical procedures applicable in turn to the methodical planning of a research, to the practical tasks of sampling, observing, estimating limits of error, assembling and classifying experimental data, and eventually analysing the results and ensuring that none but valid conclusions are drawn from them. The mathematics necessary to justify these statistical techniques has been kept as simple as is possible without being unconvincing, while the more general methods of mathematical approach to the reduction of experimental results are the concern of a separate chapter which includes a useful account of dimensional analysis. Some notes on methods of computation, ranging from arithmetical approximation to elaborate calculating machines, will be helpful to many research workers, though to a more limited extent than the concluding chapter on reporting the completed work, which is of general application and can hardly be too carefully studied by any scientist who has done a worth-while piece of work and appreciates the importance of publishing it.

Although Professor Wilson, as a physical chemist, has inevitably emphasised those aspects of research method which assume special importance in the sciences related to his own, he has purposely endeavoured to include specific topics only if they are likely to be useful to working scientists in more than one field. Many of his examples, consequently, have at least a bearing on engineering research, while the whole of his general matter forms an excellent introduction to an investigation in any of the physical or mechanical sciences. A worker of graduate standing, embarking on a first research undertaking, will probably content himself with a reading of the more elementary parts of the book, but his own growing experience will enlarge his appreciation of Professor Wilson's work and in due course encourage a fuller, and correspondingly rewarding, study of everything that the book has to say and to suggest.

Principles of Aerodynamics.

By PROFESSOR DANIEL O. DOMMASCH. Sir Isaac Pitman and Sons, Limited, Pitman House, Parker-street, Kingsway, London, W.C.2. [Price 45*s.* net.]

THE author, who is a noted American engineer, states that this book was conceived as a joint effort between the late Dr. A. Klemin and himself. To quote from his preface: his "purpose is to describe and define physical laws which are basic to aerodynamics and the methods used to apply the laws to specific problems." For this purpose sufficient mathematical analysis has been given to make the methods readily comprehensible to the student of aerodynamics. The book suffers from the fact that, as well as trying to present the elementary theory in detail (which in most cases is unnecessarily long), the author has attempted to include too many separate fields of aerodynamic theory. It is inevitable, therefore, that there are many omissions in each field. For instance, nothing is written about the methods for calculating profile drag. A further omission is that few of the theoretical results are compared with experimental data. This fact may easily give the student the wrong impression that theory alone can give the answer to any practical aerodynamic problem.

The work is divided into twelve chapters which between them cover the aerodynamics of inviscid incompressible and compressible fluids and some effects of viscosity. In addition, there are short accounts of the derivation of the conservation equations and an introduction to complex variable theory. Chapters 2, 3, 5 and 6 deal with the stream function and velocity potential of sources, sinks and vortex flows, and their applications to the flow over aerofoils. In chapter 7 the compressible-flow laws are introduced, as well as the derivation of the normal shock-wave relations and their application to one-dimensional flow in nozzles. Mach waves and shock waves, together with linearised theory, are discussed in chapters 8 and 9. Second-order theories and three-dimensional theory are detailed in chapters 10 and 11, and viscous effects in chapter 12. Some useful tables are given in appendices. It is rather surprising that in a text-book entitled *Principles of Aerodynamics* less than 10 per cent. is devoted to boundary layers and skin friction. Although problems are set at the end of each chapter, their scope is too limited and will give the student little practice in solving applied problems. The list of references is far from being complete; for example, of the 22 references to reports and papers none is by an author outside the United States.

Unfortunately, attention must also be drawn to certain errors and poor presentation, especially with regard to the derivation of the first law of thermodynamics in the chapter on basic considerations. For example, on page 14, $W ds = p d\overline{V}$ is only true when the work done against friction is neglected. On page 259, it is not stated that the Kutta-Joukowski relation only holds to the first order (i.e. linearised theory) in supersonic flow. On page 318 it is mentioned that in practice the drag coefficient at subsonic speeds obeys the Prandtl-Glauert law; this appears to be a direct contradiction with theory and the available experimental data. Among the few printing errors are $M = \frac{V}{V^n}$ in the list of symbols and $R' = \frac{53 \cdot 3 \text{ ft.}}{^\circ R}$, on page 17. These should read $M = \frac{V}{V_c}$ and $R' = \frac{53 \cdot 3 \text{ ft.-lb.}}{^\circ R}$, respectively. In a revised form the book might well serve as a useful reference book in the classroom, but as it is at present there is little to commend it.

THE INSTITUTION OF NAVAL ARCHITECTS.

(*Continued from page* 553.)

THE second of the papers presented at the morning session on March 26, during the Spring Meeting in London of the Institution of Naval Architects, was that of Mr. J. L. Bartlett, C.B.E., R.C.N.C., on "The Motion of an Aircraft Carrier at Sea in Relation to the Operation of Naval Aircraft." During this part of the session, the chair was taken by the President, Viscount Runciman of Doxford.

THE MOTION OF AN AIRCRAFT CARRIER AT SEA.

Mr. Bartlett, in introducing his paper, explained that, in May, 1951, at the request of the Naval Aircraft Research Committee, he had prepared an estimate of the maximum vertical movements, velocities and accelerations that might occur in the various parts of the flight deck of an aircraft carrier under conditions representing the limits beyond which the operation of aircraft would not be possible. The information was of importance to aircraft designers in relation to the strength of undercarriages, and the effect on the behaviour of aircraft at the moment of leaving the catapult. The paper surveyed the assumptions made, the investigations analysed, the data used and the ultimate results obtained. It was concluded that, for all practical purposes, there was a maximum wave height corresponding to a specified surface velocity of the wind; that wave height built up fairly rapidly and remained at a relatively constant value, irrespective of the duration of the wind, provided that there was a reasonable "fetch"; and that the wavelength (unlike the wave height) continued to grow with a constant wind, so that, at the beginning of a storm, the waves were short and steep, and, as the storm continued, they became longer and less steep. Assuming a "fetch" of not less than 100 miles for surface winds up to 30 knots, increasing to 200 miles for winds up to 80 knots, the maximum wave heights would range from 3 ft. for a surface velocity of 10 knots to 35 ft. for a velocity of 50 knots. The wavelengths ranged from 65 ft. for a 10-knot wind to 1,030 ft. for a 40-knot wind. Waves travelling beyond a storm area developed into a smooth swell, the length of which increased while the height decreased by about half in travelling a distance in miles corresponding numerically to the length of the wave in feet; thus a swell 1,000 ft. long would lose half its height in travelling 1,000 miles.

The damping of pitch and heave of a ship was mainly due to the generation of waves, the contribution due to friction being generally small. The damping coefficient for heaving was proportional to the square of the waterplane area, and for pitching, to the square of the moment of inertia of the waterplane area. The shape of the sections below the waterline affected the magnitude of the damping coefficient, V-shaped sections possibly producing more damping than U-shaped sections, and the damping effect decreased with the ship's speed. The periods of pitch and of heave were dominated by the period of encounter to such an extent that the natural periods of pitch and heave had little meaning; for all practical purposes, the periods of pitch, heave and encounter were the same. The freeboard in an aircraft carrier should not be less than 6 per cent. of the length on the waterline, and preferably 6·5 per cent. or more, and there should be no obstructions likely to throw up spray.

DISCUSSION.

The discussion was opened by Rear-Admiral C. John, C.B., who said that, during some 25 years' experience of the operation of aircraft carriers, he, like others, had often experienced the frustration of being unable to use his aircraft with safety, because of the motion of the ship. It was often possible to take advantage of the periodical steady period to receive aircraft on deck, but he feared that, with the general use of jet aircraft, it might be impracticable to wait for a steady period because of the high fuel consumption of jet engines. The motion of aircraft carriers had a direct bearing on the design and the strength of aircraft undercarriages, which they were "desperately anxious" to reduce in size and weight.

It was most important, therefore, that the study of aircraft-carrier motion should go hand in hand with the study of aircraft approach and landing characteristics, because the landing was more influenced by motion than the take-off. The technique of landing on the deck of a carrier was about to undergo a considerable change, combining faster approach speeds, a constant angle of approach path, angled decks, and the substitution of mechanical for human deck-landing aids. All those factors led to a more accurate arrival relative to a point on the deck. It seemed likely that the point would be farther forward than previously, and consequently closer to the null point; presumably, that was a good feature. The whole process of approach and landing would probably become more predictable and more precise, which might be a good thing or a bad thing, when related to the ship motions which were not precise. It certainly stimulated greatly the renewed interest which operators had in the study of aircraft-carrier motion, to which, he believed, Mr. Bartlett's paper was an extremely valuable contribution.

Captain H. A. Traill, C.B.E., R.N., said that, so long as the present characteristics of aircraft remained, the ship movement would impose limitations on their operation. He did not quite agree with Mr. Bartlett that the landing was limited by out-to-out movement to the degree that he suggested; he had seen aircraft landing-on when there had been an out-to-out movement of 56 ft. Modern aircraft and the aircraft of the future, of course, would make such an achievement impossible. However, until vertical or near-vertical descent by aircraft was normal—which was a very long way off indeed—they would have to keep the ship movement to a minimum. The point he wished to make—subject to correction—was that, apparently, the ship would have to be something like 1,000 ft. long to give the optimum conditions for the operation of aircraft in relation to pitch. That meant a very large ship; which was a matter of considerable interest when considered in relation to the previous paper, on the subject of docks.

Captain A. S. Bolt, D.S.C., R.N., recalled an accident which, he thought, was significant in relation to the pitching of flight decks. A wind of about 9 knots, combined with a swell from the same direction as the wind, caused a deep irregular pitching motion of the ship, and, on one occasion, it was not possible to anticipate heavy pitching in time to wave off an aircraft which was in the act of landing-on. A Sea Fury engaged No. 3 arrester wire at a rather high rate of descent, just as the flight deck was rising rapidly. The aircraft bounced high, remaining engaged in the wire; and, on hitting the deck again, a tyre burst and the undercarriage collapsed. The resultant damage to the Sea Fury was found to be excessive, the airframe structure having suffered seriously by the transmission of stress through the front undercarriage mounting. There was nothing about the weather as such which would have prevented flying, but for some unaccountable reason, the motion of the ship appeared to be out of all proportion to the state of the sea. Therefore, he could not subscribe entirely to the author's statement that "It has been asserted, on good authority, that the regular seaway represents the most unfavourable conditions when compared with any arbitrary seaway, provided the maximum wave dimensions are comparative." It seemed desirable to know a lot more about the effect of swell. He agreed that aircraft could be launched so long as heavy spray or water did not come over the forward end of the flight deck, but he did not agree that aircraft could necessarily be landed under conditions that admitted of aircraft being launched; in general, safe landing conditions ceased long before safe launching. It was difficult to accept the figures given for the maximum speed attainable at full power in waves of various lengths. Experience seemed to indicate that higher speeds could be attained, though the possibility remained of heavy bumps forward, and risk of structural damage to the ship. There might be many occasions on which high speeds were necessary under those conditions in order to launch or recover aircraft.

Mr. V. G. Shepheard thought that a few remarks about the background of the investigations would emphasise their importance in aircraft-carrier design. The problem of the efficient design of such ships in relation to future naval aircraft involved even closer examination of flight-deck detail if maximum operational efficiency was to be achieved. Full aerodrome runway facilities for aircraft of increasing weight and speed had to be provided on a flight deck of very restricted length and width. As an example, it was probable that a runway of about 6,000 ft. length would be required on shore for aircraft which would have to be operated in H.M.S. Eagle within a length of about 800 ft. That restricted length in the ship had to be shared between flying-off, landing-on, safety-barrier and aircraft park requirements. Moreover, the flight deck was liable to have considerable movement. The exploit of the Swordfish aircraft from the Ark Royal in locating and attacking the German battleship Bismarck was carried out in a rough sea, with wind force 7, and with the after end of the flight deck stated to be rising and falling through 56 ft. Not only did the motion of the flight deck call for the highest standards of skill on the part of the pilots, but it involved important technical problems. The aircraft had to be strengthened against the touch-down velocities and accelerations involved. If the strengthening was overdone, there was a penalty in overall aircraft performance. It was important to know the probability of the occurrence of violent motions, for it would not do to penalise naval aviation by over-insuring in undercarriage strength and in other ways. The pitching and heaving of the ship also provided problems in operating catapults and arresting gear. They affected even the approach technique of the aircraft themselves when landing-on, as more strain was thrown on the undercarriage and more severe conditions upon the arresting gear. With the great increase in speeds of flying-off and landing-on, it was all the more necessary to have the maximum of assistance from air velocity down the deck with the ship steaming into the wind. That valuable air velocity was reduced if the ship's speed was badly set back in a seaway. There might be a temptation to regard the loss of ship speed as insignificant in comparison with modern aircraft speeds, but that was not so; five knots lost or gained might be of the greatest importance in operating naval aircraft.

Mr. R. W. L. Gawn quoted the author's statement regarding the severe loss of speed in waves approximating in length to that of an aircraft carrier of, say, 710 ft. length and 32,000 tons displacement. The maximum sea that would not entail a reduction of speed was also of interest, and, for that particular ship, appeared to be represented by waves about 200 ft. long and 5 ft. high. Ship oscillations were also negligible in such waves, as might be inferred from other diagrams in the paper. Taken in conjunction with the average probability curve, the result implied that, for 50 per cent. of the time spent in the oceans of the world, the ship would be free from oscillations and from any loss of speed due to seas. Peak motion and loss of speed might be expected for about 15 per cent. of the time. Those interesting conclusions were applicable to the particular size and form of the ship considered. It did not follow that the same would be true for all ships of the size considered by the author, since model experiments confirmed that form and loading played an important part. It would be interesting to have the author's views concerning the effect of hull form. There was much wisdom in the author's remarks concerning the appropriate freeboard for carriers. It would be of interest to have the views of merchant-ship designers, and experience with liners. While the figures quoted were a good standard for ships of the size of carriers, there might be some point in arranging a larger coefficient for shorter ships since testing seas were met more often by a ship of smaller length.

Professor Sir Thomas Havelock said that Mr. Bartlett's paper was a mine of information, co-ordinated and applied to the problem under consideration. In the paper it was assumed that the periods of pitch and heave were the same, and that the respective motions were in the same phase; and it was said that there was considerable evidence that those assumptions were correct. Was the evidence referred to that of actual observation and experiment, or were there theoretical considerations also? In the flight-deck plan which the author gave of an aircraft carrier, indicating the movement, there was a space marked "null point," which seemed to be the crucial point. Of course, for any motions of heaving and pitching there was, at any moment, an instantaneous centre of rotation; but the position of that point would, in general, move backwards and forwards. There could be a stationary centre of rotation if, and only if, the periods were the same, and if the phases of the motions were the same or differed by 180 deg. Consequently, if such a point were found to exist, those inferences were a necessary consequence. Mr. Bartlett referred to the possibility of a modification of the damping putting the motions out of phase; but the difficulty was rather, how did they come to be in phase? According to the usual simple theory, the exciting forces causing heave and pitch differed in phase by 90 deg.; the damping was probably of the same order in the two cases, but in any case it did not seem likely that damping could abolish a difference of phase of 90 deg. It seemed necessary to look to a more complete theory of the exciting forces for an explanation, taking account, for instance, of the actual position and attitude of the ship in relation to the waves and, if possible, the effect of the motion of the ship through the waves. Such a theory might possibly bring the exciting forces for heave and pitch approximately into phase under special conditions. Was the phenomenon of the null point special in any sense?

Professor A. J. Sims said that the ordinary curve for dynamic response was a very vital curve in the understanding of pitching and heaving; he thought that it was because it could not be applied so easily to pitch and heave as to rolling that they were still far from a clear understanding of those phenomena. At present, they were forced, through lack of knowledge, to relate amplitude of pitch to the maximum wave slope and to relate the amplitude of heave to the maximum wave height. Those were not true physical comparisons, however, and knowledge of the subject was somewhat fogged until the correct physical parameter could be chosen. He had analysed some tank experiments in trying to relate certain assumptions for the damping coefficient for an aircraft carrier to an increase in the longitudinal inertia due to entrained water. Those two complicated factors in pitch and heave were closely related, and were difficult to separate, but he did get a fairly close representation of the tank results by taking a value of K slightly less than 0·5 for pitching, and an increase of inertia due to entrained water rather less than was usually assumed; it was his own opinion that there was a tendency to emphasise the effect of entrained water to a greater degree by neglecting the effect of the heave damping. Foreign papers did not use the same value of K; in America, he thought, the value was doubled, and, on that account, students of the subject had to be careful in the reading of such papers.

Mr. W. A. D. Forbes said that Captain Bolt had referred to an aircraft landing on the deck picking up the third arrester wire and then jumping off the deck and coming down again with a heavy crash; he attributed that to the ship coming up at the moment the aircraft was coming down, but there was another possible explanation. He was rather surprised to find how low were the figures given for the acceleration. At the bow of the ship, there was only $\frac{1}{4}g$, at the stern only $\frac{1}{4}g$, and halfway between the stern and the null point, where probably the bulk of the landings took place, it would be of the order of only $\frac{1}{4}g$. Those figures were not recommended, of course, and he thought the incident might have been due to the downward component of the arrester gear, which could be quite considerable, rather than the vertical acceleration of the ship.

Mr. D. I. Moor, referring to the author's graph indicating the percentage probability of meeting waves of specified heights, taken from some 20,000 to 40,000 readings by the German Schumacher expedition, thought that there was every justification for accepting those results. Later in the paper, the author stated that the probability of meeting waves longer than 800 ft. (height 20ft.)

POWER JETS' GAS-TURBINE PATENTS.

Fig. 1.

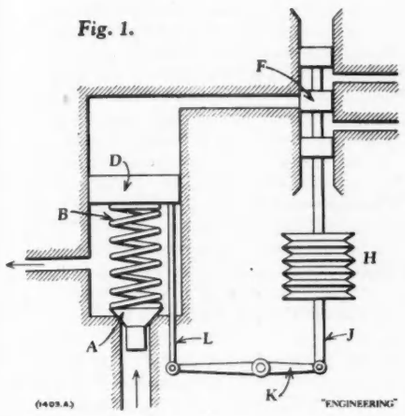
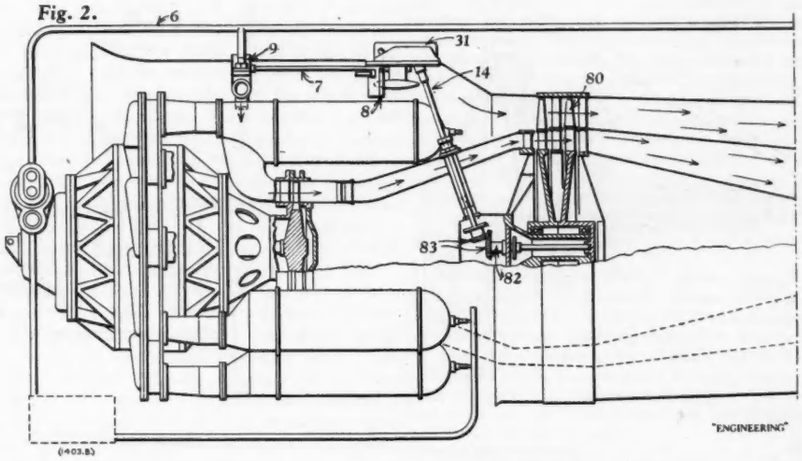


Fig. 2.



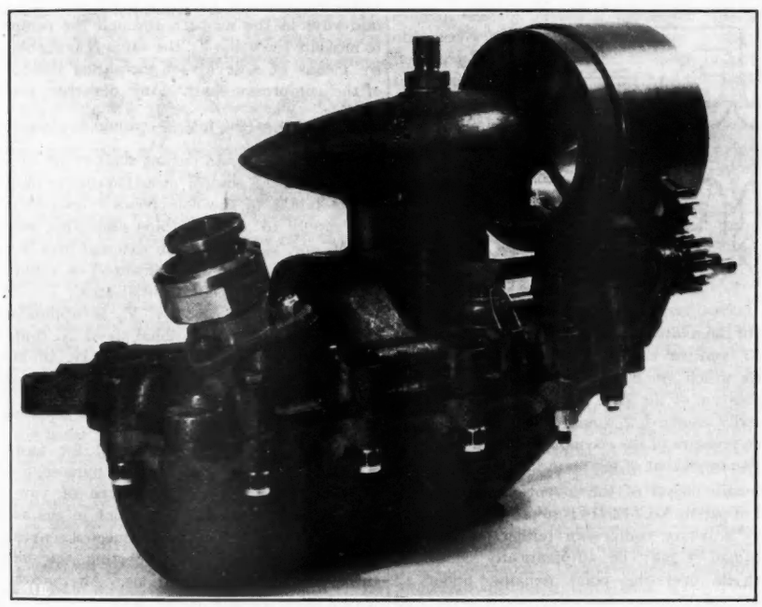


FIG. 3. CONTROL BOX FOR SECONDARY-FUEL SUPPLY.

was 9 per cent. for all the oceans, and 15 per cent. in the North Atlantic. Swells of 2,000 ft. had arrived at Cornwall, but, he believed, a proper storm wave of 800 ft., far from being likely for 15 per cent. of the time, had never been recorded in the Atlantic. With regard to the author's graph showing maximum speeds at full power in waves of different lengths, one of the naval speakers had said that speed losses of the order suggested were not often experienced. The explanation might be that wavelengths of more than 600 ft. were not often experienced. In the Atlantic, he thought, a length of about 300 ft. would be nearer the average.

Mr. Bartlett, replying to the discussion, said that, when he was asked to give to the Naval Aircraft Research Committee some figures of the movements that might be expected in the deck of a carrier, he could easily have said that it was impossible to do so; that there were so many factors to be taken into account that it was not an exact science and that there was no way of estimating. In producing the data, he found that he had to use the facts as far as they were available; where they were not available, he had to make a random choice from among, perhaps, differing authorities, and sometimes to make a guess. He was under contract to produce figures, however, and they were trying hard to see how nearly right those figures were. The point had been made that the landing of aircraft on a deck was more influenced by motion than was the take-off, and that landing-on had to be given up before flying-off. The assumption was made that operating aircraft ceased when the water came over the forward end of the flight deck. If the aircraft could not fly off, they would not have to land. In some cases, the landing might be critical, and in others the take-off might be critical.

There had been some reference to the curves of loss of speed in a seaway; he thought that the loss did occur, but that it was not often that a ship met such large waves as those mentioned, as Mr. Moor had said. Before getting the material together, he had a fine opportunity to obtain data recorded in a minesweeper which was going across the North Sea and back. The captain promised to run the ship head on to the sea. The speed through the water was measured by log and the power was measured, and the speed in still water was deduced. He was able to work out the loss of speed in waves of certain lengths, and the points on the graph showed the general nature of the curve given in the paper for loss of speed. In one of the experiments there was no null point at all; at one moment, it was miles astern and the next moment it was miles over the bow. They concluded that the ship was heaving and that there was no pitching. He suspected that long waves would produce that effect.

The meeting was then adjourned until the afternoon.

(To be continued.)

POWER JETS' GAS-TURBINE PATENTS—IV.*

AUTOMATIC CONTROL OF GAS TURBINES.

THIS section follows three earlier sections dealing with patents concerned wholly or mainly with aeronautical applications of the gas turbine; while all the inventions to be reviewed herein were originally conceived during the study of problems connected with the control of aero engines, several of them, as will appear, are equally capable of beneficial application to the control of gas turbines (and, in some cases, to the control of other equipment as well) used for other purposes. The section is concerned mainly with control systems designed to cater for the effect of external influences and it is not proposed to deal with patents concerned with fuel systems at large or with purely internal features, such as relief-valve arrangements designed to maintain a desired pressure within a fuel system, "dump" valves and the like.

The first patent in this section, No. 600,654, relates to the well-known Barostat, which is widely used to regulate the supply of fuel to an engine in accordance with the changing requirements due to changes in altitude. The Barostat may take many constructional forms but a typical arrangement is illustrated by the diagrammatic representation here reproduced as Fig. 1. In the arrangement shown, the pressure of fuel to be supplied to a burner system is controlled by a relief valve A, the resilient load upon which of a spring B is varied by means of a barometric capsule H. The capsule controls a servo-valve F by way of which pressure fluid may be admitted to or exhausted from a cylinder in which moves a piston D forming an abutment for the spring and mechanically coupled to the capsule by a linkage J, K, L.

Patent No. 603,780 is concerned with the control of secondary fuel, which term may include both afterburning fuel and fuel burned in a secondary-air stream such as that of a by-pass or other ducted-fan engine. Since the flow of air through a rotary stream-producing device (e.g., a compressor or ducted fan) is affected by the burning of fuel downstream thereof, automatic control of a secondary-fuel supply is desirable to prevent, say, stalling of the device due to the supply of fuel being too great in relation to the speed of rotation and the velocity of the air fed to the device (which velocity will, of course, vary with the forward speed of the aircraft). In the arrangement here illustrated by Fig. 2, a differential gear 31 is employed to vary the supply of fuel to be burned downstream of a ducted fan 80 when the gearing detects departure from a pre-

* Part III appeared on page 549, *ante*.

POWER JETS' GAS-TURBINE PATENTS.

Fig. 4.

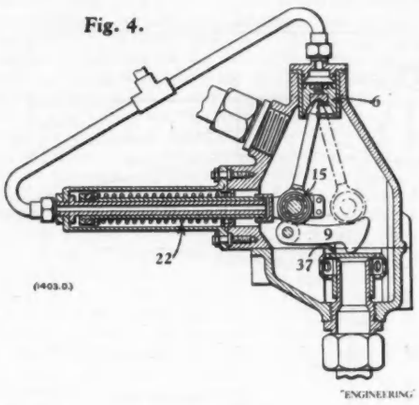


Fig. 6.

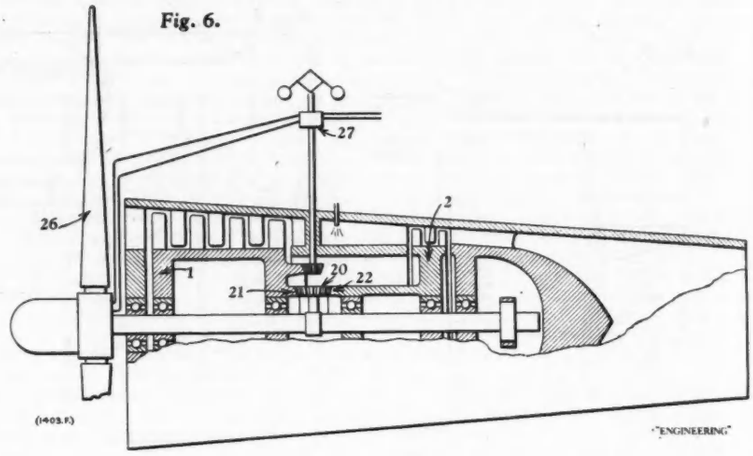


Fig. 5.

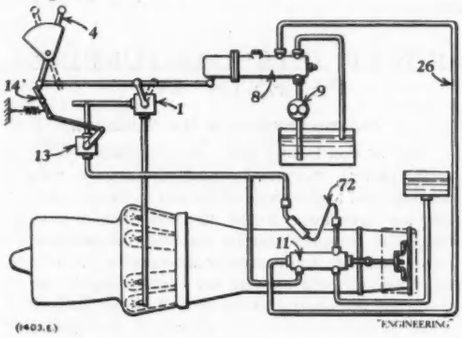
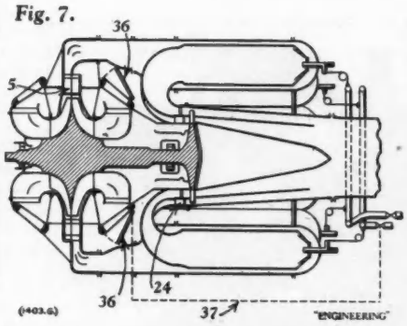


Fig. 7.



determined value of the relation between the rotational speed of the fan (fed in via 82, 83, 14) and the inlet velocity of air supplied to the fan, as measured by a windmill 8; the actual control of secondary-fuel supply is effected by means of a spill valve 9 which is connected in parallel with the supply line 6 and is adjusted by the differential gear through a spindle 7. Variable incidence inlet guide vanes may be provided to vary at will the angle of attack of the inlet air upon the vanes of the windmill. The photograph reproduced as Fig. 3, on page 583, is of interest as it shows a prototype control box (differential gear) produced to control the secondary-fuel supply for the M52 project mentioned in a preceding section (Section II—Thrust Augmentation).

Although also intended primarily to be applied to the control of secondary fuel, the invention forming the subject of the next patent (No. 605,437) is applicable in general to the control of the pressure of one fluid (liquid or gaseous) in accordance with that of another; a particularly appropriate application is to a case in which an altitude or other over-riding control is required to operate in common upon the two fluid systems. The apparatus illustrated by Fig. 4 comprises a flow-regulating device (the relief valve 37, or a variable-delivery pump could be employed as an alternative) which controls a first pressure (e.g., that of a secondary-fuel supply) and is loaded through a pivoted lever 9, to which a turning moment is applied from a piston 6 which is subject to a second (controlling) pressure (e.g., that of the fuel supply to the main combustion system of a jet-propulsion engine). The turning moment applied to the pivoted lever may be progressively modified through the action of a second spring-pressed piston 22, which is also subject to the controlling pressure and operates to vary the position of a roller 15 through which the first piston 6 acts on the lever. The relation to be maintained between the controlling and controlled pressures may be determined by suitable choice of certain factors, that is to say, in the arrangement illustrated, of the relative areas of the piston 6 and valve head 37 and of the lengths of the mechanical elements which are interposed between them; in an application of the kind for which the apparatus is primarily intended, it would probably be required that the pressure of the secondary fuel should vary as the square of that of the main fuel supply.

The main object of the invention forming the subject of patent No. 612,414 is to provide apparatus whereby a rotary compressor (either "axial" or "centrifugal") may be automatically controlled so that its operating point remains, under all operating conditions, substantially on a prescribed operating line; although a war-time Power Jets project, and thus primarily intended for application to the control of compressors for aircraft propulsion units, this important invention is capable of general application to the automatic control of compressors and of gas-turbine plant incorporating them.

The invention is based on recognition of the fact that the operating point of a rotary compressor is uniquely related to the ratio of true rotational speed to absolute fluid velocity, i.e. $\frac{N}{V_a}$, at a selected point in the compressor and that the manner in which this ratio varies with speed determines the operating line of the compressor; thus, to achieve the desired object, it becomes necessary to maintain a constant value of the ratio $\frac{N}{V_a}$.

The specification of the patent describes many possible methods of measuring the ratio referred to above, and of controlling a compressor in accordance with the measurement; it is clearly outside the scope of a work such as the present to illustrate them all, but reference may be made again, by way of example, to Fig. 2. In that figure, there is shown an anemometer measuring air velocity at the intake to a ducted fan and driving one element of a differential gear, another element of which is driven in accordance with the rotational speed of the fan; in the present case, a similar anemometer could be mounted at the appropriate place (say, mid-way) in the air-path through the compressor to measure the value V_a, the value N being obtained by means of a device for measuring the velocity of the compressor shaft. Any departure from the chosen value of the ratio $\frac{N}{V_a}$ would be detected by a differential gear, an output shaft of which would rotate to affect a control operation such as throttling of the intake of the compressor, variation of the fuel supply to a gas turbine associated with the compressor, variation of an external load (e.g., by means of a variable-pitch airscrew) or variation of turbine nozzle or exhaust outlet area.

Since the whirl velocity V_w is approximately proportional to the rotational speed N, control in accordance with the invention may, in another example, be effected through some device capable of measuring the ratio $\frac{V_w}{V_a}$ and thus replacing the two devices previously described for measuring N and V_a, respectively. For this purpose, use may be made of a conventional type of yaw-meter mounted at the appropriate point in the air-path through the compressor and connected conveniently to a capsule device for effecting the requisite automatic control operations. Alternatively, a special form of yaw-meter may comprise orifices situated in the upper and lower surfaces of a stator blade, or in the upper and lower surfaces, respectively, of two stator blades in the same row, the orifices being located so that, at the blade incidence corresponding to the prescribed value of $\frac{N}{V_a}$, they experience equal pressures.

Patent No. 659,800 is concerned with control of the jet characteristics of a jet-propulsion unit in accordance with certain conditions which may be referred to as "pilot-influenced" to distinguish them from "external" conditions, such as altitude and forward speed over which the pilot has (so to speak) no control and which may also be required to be taken into consideration if the area of the propelling nozzle is to be maintained at the optimum value for performance and efficiency. The "pilot-influenced" conditions are all, in effect, linked up with the position and movement of the throttle lever or its equivalent and the considerations upon which the invention is based are: (*a*) when the plant is idling, the thrust generated should be kept as small as possible to facilitate landing and generally to improve the deceleration characteristics of the aircraft; (*b*) rapid acceleration of the power plant may be facilitated, and excessive rise of jet-pipe temperature during this phase may be prevented, by temporary reduction of the back pressure on the exhaust system; and (*c*) no variation of jet charac-

teristics is required during deceleration of the power plant (unless and until idling condition is reached). The diagrammatic drawing reproduced as Fig. 5 opposite, illustrates an arrangement in accordance with the invention and wherein an "opening" movement of the throttle lever 4, in addition to setting the main fuel supply controller 1, actuates a hydraulic transmitter 8 in such a way that the line 26 leading to a hydraulic receiver 11 is energised by the output of a pump 9; as a result of such energisation, the receiver acts to increase the area of the propelling nozzle, thus decreasing the back pressure on the accelerating engine. When the movement of the throttle lever ceases, a follow-up device within the transmitter becomes operative to de-energise the line to the receiver, whereupon the propelling nozzle area is returned to normal by spring action. Upon "closing" movements of the throttle lever, no energisation of the line to the receiver takes place but entry of the lever into the idling range is accompanied by energisation and the nozzle area is again increased and remains thus during all idle running. The arrangement illustrated also includes means (14, 13, 72) whereby location of the throttle lever beyond the "normal" maximum power setting results not only in fuel being supplied to an afterburning system but also in the area of the propelling nozzle being maintained at maximum value.

The specification of patent No. 595,357 discloses several arrangements intended to permit flexibility of operation in cases in which there is no separate power turbine; the feature common to all the arrangements is the provision of differential transmission mechanism whereby a compressor and a rotary load may be driven by the same turbine rotor but at different, though inter-dependent, speeds. The invention is illustrated by Fig. 6, opposite, in which are depicted a turbine rotor 2, a compressor rotor 1, an airscrew 26 and differential gearing 20, 21 and 22, whereby the two latter are driven by the former; with this arrangement, the speed of the compressor rotor will be dependent upon that of the airscrew, the former speed being a maximum when the latter is a minimum and vice versa. In the example illustrated, it is assumed that constant compressor speed is required, in the interests of efficiency, and the airscrew pitch-changing mechanism is placed under the control of governor mechanism 27 driven from the compressor rotor; in an alternative but equivalent arrangement, pitch-changing could be controlled by means of a device sensitive to the compressor delivery pressure. Among the other arrangements described in the specification is one proposed for marine propulsion and in which mechanical differential gearing is replaced by an electrical equivalent; in this case, the turbine drives a generator while the compressor and the screw are each driven by an electric motor, the two motors being connected in parallel in the output circuit of the generator.

The final patent (No. 616,786) to be reviewed in this section could perhaps be said not to be qualified for inclusion here, since the control is "manual" rather than "automatic"; it is included in view of the fact that it provides an inter-linked control between a compressor and an associated combustion system whereby fuel economy may be achieved in certain conditions of operation. While capable of wider application, the invention was primarily conceived with a view to economy of fuel consumed, particularly when cruising at low altitudes, in gas-turbine aero engines of which the maximum power output is required, in the interests of high top speed and climb performance, to be large in relation to that required for cruising. In the example illustrated by Fig. 7, opposite, the power unit comprises a centrifugal compressor with a double-sided impeller and the outputs from the two sides of the impeller are received by distinct diffuser systems separated from each other by a splitter plate 5; one diffuser system delivers to half the combustion chambers, the other system delivering to the remaining chambers, which alternate with those receiving air from the first system. The nozzle-box of the turbine is divided, by a shroud ring 24, into inner and outer annular flow paths, of which the former is associated with the combustion chambers fed by the rear side of the impeller and the latter with the remaining chambers. Valve members 36 are provided to render the rear half of the compressor inoperative (or nearly so, if a trickle of air is required for, say, cooling purposes) and a linkage (indicated by the dotted line 37) is provided whereby blanking-off the rear half of the compressor is accompanied by shutting off the supply of fuel to the associated combustion chambers.

It will be noted that, when the unit is consuming approximately half the normal air-flow and producing approximately half the maximum thrust, the hot gases are acting upon the outer, more efficient, portions of the turbine blades; this arrangement should tend to offset the losses to be expected, for instance due to pumping of a small quantity of air through the inoperative combustion chambers and to sudden diffusion in the exhaust system, thereby enabling the lower thrust to be obtained without substantial change in the specific fuel consumption (reckoned in terms of pounds of fuel per second per pound of thrust). Apart from the advantage of fuel economy, the great reduction in thrust obtainable when the air consumption is halved is beneficial to the pilot when approaching to land, especially in the case of carrier-borne aircraft.

GAS HEATING OF LEAD-MELTING POTS FOR CABLE SHEATHING.

A SERIES of tests has recently been carried out by the North Thames Gas Board at the works of Metropolitan Cables, Limited, Chadwell Heath, Essex, to determine the performance of two lead-melting pots. These pots are used to supply lead to an extrusion press for sheathing electric cables, and have capacities of 5 and 2½ tons, respectively. The metal, in the form of 50 to 60-lb. ingots, is melted in the larger pot and, after the dross has been removed, is run by gravity into the smaller pot where it is maintained at a temperature of 375 deg. C. until it is charged into the press. Both pots are heated by gas which is supplied through a 1½-in. pipe and a thermostatically-controlled and electrically-operated valve to a Hypact burner in the combustion chamber. There is also an independent pilot supply to each pot which is given through a ¾-in. pipe. The smaller pot has, in addition, an interlocking pilot cock. The channel through which lead is run from the larger to the smaller pot is heated by a drilled-bar burner. The gas consumed by the pilot supplies and the burner heating the valves and connecting pipe, as well as that used in maintaining the temperature of the press, is not included in the test figures given below. The heat so supplied has, however contributed to the process and, in the case of the pilots under the pots, was almost sufficient to maintain the temperatures at equilibrium. The full-on gas rates were 655 cub. ft. per hour for the small pot and 667 cub. ft. per hour for the large pot, both pots operating at a burner pressure of 1·4 in. water gauge.

Two series of tests were carried out to determine the efficiency of the plant in terms of tons of metal melted per therm of gas consumed and to discover the amount of gas consumed per yard of cable sheathed. During a working day of about nine hours, a typical test showed that the total weight of metal melted was 8,144 lb., the gas consumption being 2,000 cub. ft. in the large and 900 cub. ft. in the small pot. The calorific value of the gas was 503 B.Th.U. per cubic foot, the metal melted thus amounting to 560 lb. per therm, or 4 therms per ton. Over a period of 24 hours, the gas consumption for the same amount of metal melted was 8,200 cub. ft., of which 3,400 cub. ft. was consumed during the night in the large, and 1,900 cub. ft. in the small pot, the metal melted, again 8,144 lb., amounting to 198 lb. per therm or 11·3 therms per ton. The quantity of metal melted per cubic foot of gas consumed must obviously vary according to the type of cable being sheathed. For instance, the larger diameter cables require more metal per yard run, so that while the amount melted will be greater, less gas will be consumed in maintaining it at temperature before it is used. If there is a breakdown, however, and no metal is used for several hours, gas will be consumed to maintain the metal at its working temperature. Another factor contributing to variations in the gas consumed per pound weight of metal melted is the need to change the dies several times during the day.

To illustrate these facts, figures have been calculated for typical cables identical with those set out in Table III of British Standard specification No. 480 of 1942. These figures enable the number of yards of different types of cable sheathed per cubic foot of gas consumed to be compared. For this calculation, a figure was taken of 3·1 lb. of metal melted per cubic foot of gas and the results are shown in Table I below.

TABLE.—*Yards of Cable Sheathed per Cubic Foot of Gas Consumed.*

Outside Diam. of Finished Cable, In.	Thickness of Lead, In.	Volume of Lead Per Yard Run of Cable, Cub. In.	Calculated Weight of Lead Per Yard Run in Lb. (Wt. of Lead 0·408 Lb. Per Cub. In.)	Yards of Cable Sheathed Per Cub. Ft. of Gas Consumed During Working Day (Calculated).
0·710	0·060	2·37	0·0675	3·2
1·442	0·1	7·2	2·91	1·16
1·740	0·080	7·8	3·18	0·975
1·740	0·090	8·64	3·52	0·88
1·760	0·090	9·06	3·70	0·84

PREVENTION OF FUEL-PIPE FAILURES BY DAMPING.

AN investigation into the causes of failure of high-pressure fuel pipes on Diesel engines, which has been carried out by C.A.V., Limited, London, W.3, has enabled the firm to introduce a simple damper with a synthetic-rubber bush which, by restraining the fuel pipe at about its mid-point, effectively reduces vibration of the pipe and thereby obviates failures.

The frequency of failure of high-pressure fuel pipes, which has been experienced with many, if not all, makes of Diesel engine, varies greatly both from engine to engine and from operator to operator, from a pipe life of three years or even longer to frequent failure after a few weeks. There seems to be no type of engine which can be said to be free from pipe failures everywhere. On inquiry, a number of users, who when first approached said that the trouble was unknown, subsequently found that in fact breakage was surprisingly common. Failure usually consists of a break, more or less transverse, generally at the nipple; but with some terminations other types of failure, causing leakage rather than breakage, occur first. Past work has been on the fatigue strengths of the normal single-taper pipe ends, some other forms of termination, and on pipes of some different materials. Some improvement of fatigue strength was found possible, but uncontrolled trials in service did not appear to show any considerable improvement. While C.A.V., Limited, have supplied fuel-injection equipment for a wide range of engines, the high-pressure pipes have been supplied generally by the engine builder. However, it seemed logical for the company to investigate the problem to find a means of eliminating failures, and accordingly work was put in hand.

High-pressure pipes are almost invariably of mild steel and, in engines of up to 10 litres, or thereabouts, of 6-mm. outside diameter. There are many different terminations, however, some of which are shown in Fig. 1, on page 586; (*a*) to (*d*) have been widely used, and there are a few others not in common use and not illustrated. The commonest termination, Fig. 1(*a*), is the single

taper made by upsetting or swaging with a hand tool, with a steel backing washer. The double-cone end has generally, but not invariably, been found to be an improvement over the single taper as regards breakage, but with some trouble due to washer failure and consequent leakage. The loose brass olive was sometimes found to reduce breakages but with an increase of leakage. Various forms of pipe clamping have been tried and many are used. They are generally found to improve matters, but seldom, if ever, to afford complete freedom from failure. A number of alternative pipe materials, including Monel metal, Tungum and stainless steel, have been tried, with some improvement in the case of Monel, but without providing a complete cure.

Laboratory Investigation.

Most pipe failures examined appeared to be fatigue fractures due to transverse bending. Calculations of the magnitudes of some of the quantities involved are of interest. If a high-pressure pipe 20 in. in length is held firmly by the pump at one end and the nozzle holder at the other, a displacement at the middle of 0·1 in. produces a stress at the ends of about 10 tons per square inch. This is the fatigue limit of the normal single-cone terminations. The lateral displacement of one end of the pipe relative to the other which would produce this stress is about 0·4 in., but vibration of the pump relative to the engine of this amount is, of course, inconceivable. A high-pressure fuel pipe, clamped at each end, is a highly resonant system, however, and if there is a vibration of one end relative to the other of the same frequency as the natural frequency of the pipe, stresses greatly in excess of those corresponding to the amplitude of the exciting vibration can be built up.

An amplification factor of 60 is quite possible, so that, for a 20-in. pipe, a vibration of one end relative to the other of 0·007 in. would be enough to excite a vibration of amplitude 0·1 in. at the middle of the pipe, producing a stress equal to the fatigue limit at the ends. Such a vibration must be reckoned reasonable. The amplification depends upon the damping, which is discussed later. It can be shown that the frequencies of pipes and probable engine or pump frequencies are roughly the same. The lowest natural frequency of a 20-in. pipe in transverse vibration is 100 cycles per second. This is equal to the pump-cam frequency (or engine-firing frequency) of a six-cylinder engine at 2,000 r.p.m. It seems probable, therefore, that pipe oscillations are excited by even the fundamental of the engine-firing frequency, and certainly by low harmonics of it.

The stresses actually occurring in pipes were explored by strain-gauge measurements on a typical six-cylinder engine. The gauges were attached to the pump ends of the pipes, as failure occurs more frequently at this end, and in any case the stresses at the two ends are not likely to differ greatly. Results are shown in Figs. 2 to 5. Fig. 2 is a record of the vibrations resulting from plucking a pipe with the engine not running. The very slow decay of the oscillations is an indication of the very low damping of the system, showing that resonances of large amplitudes are likely. Fig. 3 is a record taken at a speed chosen at random to indicate the general level of stress in the pipe; at certain speeds, however, much larger amplitudes are found. Fig. 4 shows the most severe resonance observed on this engine. The fact that the vibration is resonant is demonstrated in Fig. 5, which shows the effect of laying a finger lightly on the middle of the pipe. This small amount of damping was enough to reduce the stress many times.

The largest stress observed on this engine was about ±6 tons per square inch. This is well below the fatigue limit of the single-taper ends (10 tons per square inch), but it is to be expected that the actual magnitudes of such resonant vibrations will vary greatly from engine to engine and from condition to condition. Even this installation, therefore, cannot be said to be out of danger. Several engines have been examined, and maximum stresses ranging from 5 tons to 20 tons per square inch have been found. This points to the conclusion that resonant vibrations resulting in bending stresses reaching the

FAILURES OF HIGH-PRESSURE FUEL PIPES.

Fig. 1. PIPE TERMINATIONS.

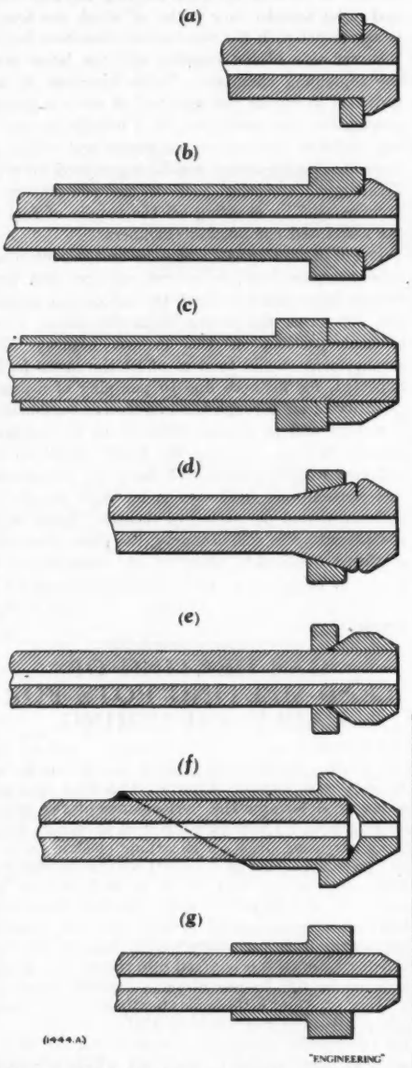


Fig. 2. M.S. PIPE ON ENGINE (PLUCKED).

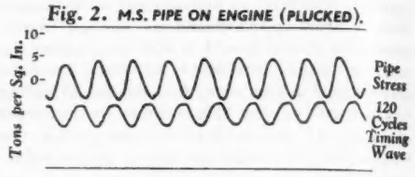


Fig. 3. GENERAL STRESS LEVEL AT 1,480 R.P.M.

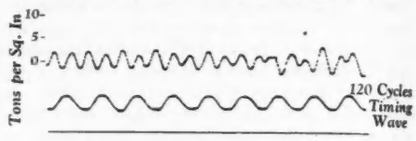


Fig. 4. LARGEST RESONANCE AT 1,415 R.P.M.

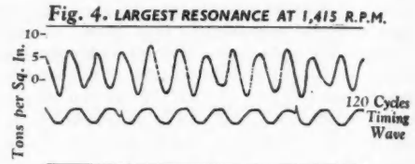
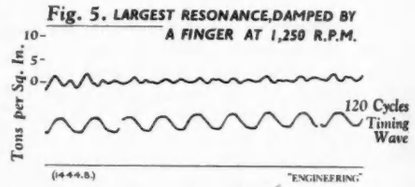


Fig. 5. LARGEST RESONANCE, DAMPED BY A FINGER AT 1,250 R.P.M.



fatigue limit of the pipe ends are the primary cause of failure. The following quantities determine the stress: (1) Amplitude and frequency of the exciting vibration, i.e., of the pump with respect to the engine; (2) fatigue limit, T, of the pipe with the chosen end fitting; (3) the damping factor, d, of the pipe at its end fitting; d is defined as the energy loss per cycle divided by the total energy of the vibration; (4) Young's modulus, E, of the pipe material.

Items (1), (3) and the pipe geometry determine strain, and stress is equal to strain × E. The relative merit of any given material and termination is determined by the expression $\frac{T\,d}{E}$. Whatever else is done, it is of the first importance that the mounting of the pump on the engine should be as rigid as possible, since, other things being equal, pipe stresses are proportional to the amplitude of vibration of the pump with respect to the engine. In practice, however, it would appear to be seldom, if ever, possible to achieve so rigid a system that pipe vibrations do not occur. The possible means of reducing failures are: (1) By increasing the fatigue limit of the pipe material and/or the termination; (2) by increasing the damping capacity of the pipe material (measurements of both damping capacity and fatigue limit have been made); (3) by imposing restraint on the pipe, for example, by clamping.

Fatigue Limit of Pipe Materials and Terminations.

Measurements of the fatigue limits of pipes of various materials with different terminations were made. A simple test-rig was used, in which a short length of pipe, held by the termination under test, was subjected to reverse bending by loading as a cantilever and rotating (the Wohler test). The results are given in column 3 of Table I.

The expected fatigue limit of the normal mild-steel pipe itself is 12 tons per square inch. Thus, the double cone end is in fact slightly stronger than the pipe itself, as is shown by the fact that such ends generally break ½ in. or so away from the nipple. The brazed terminations were also fatigue-tested and it was found that, when properly made, they were as strong as, or stronger, than the pipe itself. Although the single cone end is slightly weaker in fatigue, the loss compared with double cone or brazed ends is small, and is shown later to be trivial compared with variations in damping factor.

The effect of the termination is somewhat greater with other materials, presumably because they are more notch-sensitive. Thus, with stainless steel there is an increase from 14 tons per square inch for the single cone end to 22 tons per square inch for the double cone end. If such materials were to be used it would be worthwhile also using the double taper end. Apart from stainless steel, no material tested shows any considerable advantage in fatigue limit over mild steel.

Damping Factor.

The damping factor increases with stress and with the amount of cold-working to which the test-piece has been subjected; but if run at a stress near the fatigue limit, the damping factor decreases with time. The relevant quantity is the stable value after running at just below the fatigue limit. Measurements under this condition have been made for most of the promising materials.

To avoid failure it was generally necessary to run at a stress appreciably below the fatigue limit, probably because of occasional increases of amplitude caused by variations of the mains supply to the test equipment. In Table I, the highest stress at which it was found possible to run is given in column 5 (T′) and the final damping factor (d) is

FAILURES OF HIGH-PRESSURE FUEL PIPES.

Fig. 6.

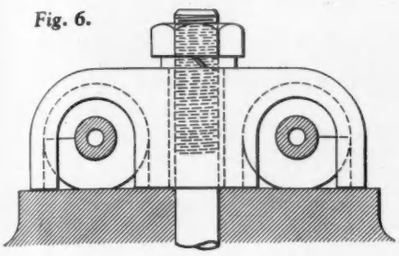
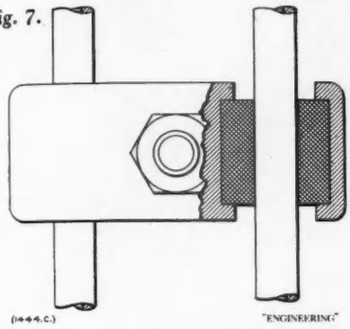


Fig. 7.



(1444.C.) "ENGINEERING"

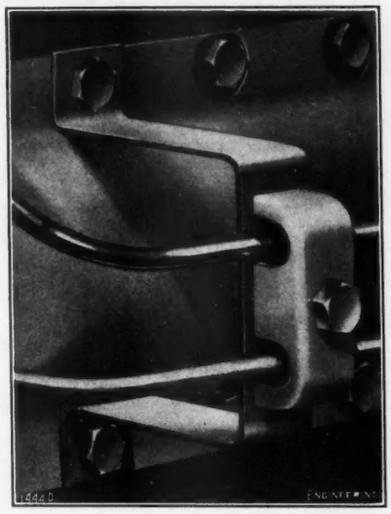


FIG. 8. C.A.V. SYNTHETIC-RUBBER DAMPER.

given in column 4. The merit of any given material and termination is given by the factor $\frac{T' d}{E}$ in column 7. Some tests were also made on stainless steel. Earlier fatigue measurements gave a high strength (22 tons per square inch) with double cone ends. Later samples from a different batch, however, made to measure damping factor, failed to give this high fatigue limit. Attempts to repeat the original behaviour have so far failed, but there remains a possibility that stainless steel would show a worthwhile advantage over mild steel.

Apart from this possibility, the value of $\frac{T' d}{E}$ given in the table shows that no material is considerably better than mild steel. Attention was therefore given to the reduction of working stresses by means of dampers, the possibility of which had been clearly demonstrated by the effect of merely laying a finger on a pipe, as described above.

TABLE I.—PROPERTIES OF MATERIALS TESTED.

Material.	End.	Fatigue Limit T, tons per sq. in.	Damping Factor d = Energy Loss per Cycle after Running at Stress T', per cent.	T', tons per sq. in.	E, tons per sq. in. × 1,000.	$\frac{T' d}{E}$
1.	2.	3.	4.	5.	6.	7.
Mild steel	C.A.V.	9·6	0·07	9·0	13·5	4·8
	Double cone	12·4	0·07	8·0		4·2
Hard nickel ..	C.A.V.	9·0	0·06†		13·0	4·1
Soft nickel	C.A.V.	9·5	0·095	8·0	13·0	5·8
Half-hard Monel ..	C.A.V.	12·0	0·05	9·0	11·0	4·1
Soft Monel	C.A.V.	10·5	0·03	7·0	11·0	1·9
Everdur	C.A.V.	10·0*	0·018†		6·8	2·6

* Maker's value.
† These materials were not run to stabilise the damping factor since the initial values quoted here are too low to be of interest.

PIPE DAMPERS.

Strain-gauge measurements were made with various types of clamp on an engine which gave pipe stresses, without clamps, of up to 11 tons per square inch. It will be appreciated that in a system such that the high stresses are due to resonance, the stresses found may be capricious from one occasion to another. It is therefore necessary that for any device to be regarded as offering a cure for the breakage trouble it must give stresses very substantially less than the fatigue limit; the target set in these experiments was one half the fatigue limit, i.e., with single cone ends on mild-steel pipes, a stress not greater than 5 tons per square inch.

The arrangement most likely to be effective is one in which each pipe is connected to the engine structure by some material capable of absorbing vibrational energy. It was found that attaching the mid-point of each pipe to the engine by a clamp lined with sponge rubber was very effective, provided the clamp was not fully tightened. With the sponge-rubber lined clamp fully tightened, however, or with rigid (steel) clamps to the engine, the particular resonance giving the highest stress, with pipe unclamped, disappeared, but resonances appeared at other engine speeds which were generally almost as serious as the original one. A similar result was obtained by clamping the pipes together in pairs with either steel, wood-lined steel, or even sponge-rubber lined clamps not fully tightened. It was concluded that of these palliatives the most effective was clamping to the engine with resilient energy-absorbing material interposed.

The C.A.V. synthetic-rubber damper shown in Figs. 6 to 8 was then designed. It consists of a rubber bush which fits the pipe, the outside surfaces being held in a metal housing which fits but does not deflect the rubber. The bush is split radially so that it can be slipped on to the pipe. The effect of these dampers in reducing stresses is shown in Table II. Subsequently, tests were made on two other engines with similar results, an occasional stress of 4 tons per square inch being observed on one pipe. Figs. 6 to 8 show a twin-pipe damper.

TABLE II.—*Effect of C.A.V. Dampers.*

Pipe.	Unclamped, Worst Resonance.		Clamped, Worst Resonance.	
	Speed, r.p.m.	Tons Per Square Inch.	Speed, r.p.m.	Tons Per Square Inch.
1	1,475	11	1,200	2
2	1,630	8	1,800	2·5
3	1,290	7	1,900	3
4	1,440	7	1,800	2
5	1,450	4	1,600	1·5
6	1,580	11	1,500	4

Endurance tests were made in which the rubber was stressed much more severely than it would be in practice, by vibrating a pipe in it. Runs were made with the damper dry at room temperature, and at 80 deg. C. with gas-oil dripped on it. No considerable wear was found in 100 hours, and in view of the much more severe duty which rubber components often perform, it is expected that these dampers will last many thousands of hours; it is proposed, however, that the rubber should be replaced at engine overhauls.

RECOMMENDATIONS ON PIPE INSTALLATIONS.

(1) The pump mounting and the part of the engine structure to which it is attached should be as rigid as possible.

(2) Pipes should be clamped at about the mid-point to the engine structure. Where, to keep pipes of equal length, it is necessary to put a coil into a pipe, the coil should be neglected when estimating the mid-point.

(3) The layout should be such that the pipe is as far as possible parallel with the axis of the damper. If a major part of either half of the pipes makes an angle greater than 45 deg. with the axis of the damper, the damper may be ineffective.

(4) The pipe should be smooth at the point where it goes through the damper.

(5) In forming the pipe ends, care should be taken to avoid notching the material. Flashes should be removed only if essential to permit assembly; if they must be removed great care should be taken to avoid gashing with the file.

(6) Care should be taken, when forming nipples with a hand-operated nipple-forming tool, that undue pressure is not applied as this distorts the nipple and reduces the bore of the pipe.

(7) After formation of nipple and setting to required angle, pipes should be cleared either by blowing through with compressed air or with fuel or Shell Fusus "A" oil under pressure.

(8) If pipes are to be stored, ends should be blanked off to exclude air, or pipes submerged in a tank containing fuel or Shell Fusus "A" oil.

The C.A.V. damper is available in single, double or triple-pipe units.

AERONAUTICAL RESEARCH IN AUSTRALIA.

To facilitate new programmes of development work, some reorganisation has been carried out at the Aeronautical Research Laboratories of the Department of Supply, Australia, it is stated in their annual report for 1951-52, issued recently. There are now four main research divisions—Structures and Materials; Mechanical Engineering, which includes the laboratories' engineering and development facilities; Aerodynamics, covering broadly subsonic flow and piloted aircraft, and providing also an instrumentation service for all the departments of the laboratories; and High-Speed Aerodynamics which, as described in the previous report, summarised on page 309 of our 173rd volume (March 7, 1952), has been set up in a separate establishment at Salisbury, South Australia, for carrying out research on supersonic flight and pilotless vehicles. A summary of some aspects of the work of the Laboratories is given below.

STRUCTURES AND MATERIALS.

In connection with studies on the life of aircraft structures, the collection of load-velocity records from Australian civil and military aircraft, which are analysed for assessing the effect of repeated loads on aircraft structures, are to be supplemented by records from counting accelerometers. The full-scale laboratory tests of aircraft wings under fluctuating loads are still in progress; the results of these tests, when complete, will enable the life of similar structures to be assessed under any combination of alternating and mean loads. From the wing test data already obtained, and from known fatigue data on 75 S aluminium alloy, the life of the wing of a particular aircraft in service with one of the Australian air-lines has been estimated at between 3,000 and 13,000 hours, which is considered to be in reasonably good agreement with the actual life of 9,000 hours at which the wing failed in service.

Work on the fatigue of metals, including the effects of rate of loading, reheat treatment and overheating, and surface finish, has continued. It has been observed that longer lives are obtained for aluminium-alloy 24-ST specimens at loading rates from 10,000 to 12,000 cycles per minute, particularly at high stresses. For carrying out surface-finish tests, a method of hardening and tempering in a vacuum has been evolved which causes no change in the profile or chemical composition at the surface of the specimen. In 24-ST aluminium-alloy specimens, a significant difference in fatigue strength has been observed between specimens finished before and after heat treatment.

Continuing the investigations on chromium-based high-temperature alloys, eight binary alloys have been selected for further investigation and have given promising results, retaining a high hardness at 900 deg. C. over many hundreds of hours. Further tests on these alloys are to be carried out in compression-creep machines with temperature-controlled furnaces and adequate strain-measuring facilities, which are now awaiting final calibration. Investigation on the low-temperature brittleness of steels has been commenced.

MECHANICAL ENGINEERING.

During the past year the Mechanical Engineering Division have been working on a compressor test house and a high-pressure combustion laboratory. The latter is expected to be ready by the middle of this year. The compressor test rig is powered by a 3,400-h.p. variable-speed motor, which can be coupled either to a modified Nene compressor delivering 90 lb. per second of air at a compression ratio of 1·7 to 1, or to a Jumo compressor delivering 43 lb. per second of air at a compression ratio of 2·8 to 1. The test house—which will also form an air source for the combustion laboratory, a high-speed cascade tunnel, a ram-jet test rig, and an open-jet tunnel for investigating engine-intake flow—will be equipped with several commercial compressors.

Mechanical engineering research is divided between three groups, on flight propulsion, turbine-engine aerodynamics, and project engineering. The flight propulsion group, continuing studies in combustion design on a multiple air-supply test rig, have found that the airflow through the small annular shroud surrounding the fuel-injection atomiser has a critical effect on combustion. Tests so far have been confined to atmospheric pressure; there still remains an extensive programme of air flow investigation. Ram-jet researches have commenced with a study of the fuel distribution in a ram jet, at atmospheric pressure; it was expected that the initial experiments would be complete by the end of 1952, after which experiments at high pressure would be initiated.

The turbine-engine aerodynamics section have continued experiments on design in the low-speed cascade tunnel, which has been modified to give two-dimensional flow over a greater area of working section, by adding a boundary-layer suction slot on the top wall immediately in front of the cascade. For producing the blades with the minimum of hand finishing, contoured cutters have been developed for use in a machine in which the work can be traversed at right angles to the cutter. Three new cascades have been developed, which have shown no improvement over conventional blades in the low-speed tunnel, but which are believed to be advantageous at high speed. The vortex tunnel, now under construction, is expected to be erected at the University of Tasmania for extra-mural studies.

The project engineering group have continued development work on an open-cycle gas turbine for burning pulverised brown coal. Although the ash had no erosive effect on the blades it built up to an unacceptable degree in the turbine, and the causes for this are being investigated. Preliminary experiments on an all-metal combustor with a film-cooled flame tube have shown practically no ash deposition whereas the ceramic-lined combustor used in the coal-burning turbine tests accumulated large deposits. Fluctuations in the fuel feed rate have been overcome by "fluidising" the coal bed with air.

TEST PLANTS FOR "AVON" JET ENGINES.

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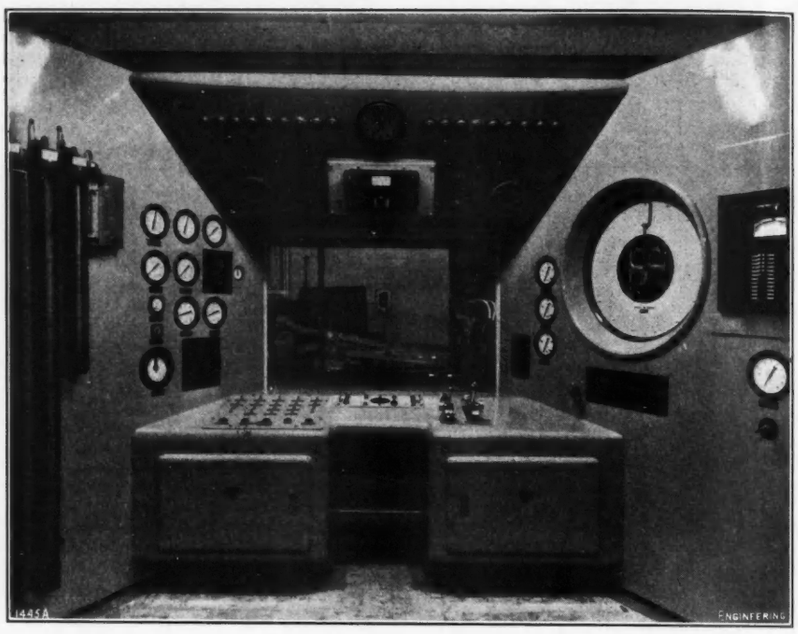

FIG. 1. CONTROL DESK.

AERODYNAMICS.

The work of the Aerodynamics Division is divided among the following groups—flight motion, stability and control, applied aerodynamics, flight research and instrumentation. The fluid-motion group of the Aerodynamics Division have started work on a project for preventing laminar separation and delaying turbulent separation on thin wings. Work on the stability and control of a radio-controlled tailless flying model has made little progress since the model crashed on the test flight, apparently as a result of poor climb performance. A direct-reading forced-oscillation equipment for the 9 ft. by 7 ft. wind tunnel is under development; a pilot model suitable for the 4½ ft. by 3½ ft. wind tunnel at Melbourne Technical College is being constructed. The 9 ft. by 7 ft. low-speed wind tunnel has been used mainly for development work for the aircraft industry. The Mach number control of the high-speed wind tunnel has been calibrated satisfactorily up to M=0·85. It is hoped to extend the operating range of this tunnel into the transonic region by using a ventilated working section. As reported last year, the cooling arrangements are still unsatisfactory and specifications have been prepared for a new cooling plant.

At Sydney University, a supersonic wind tunnel of the intermittent type is being installed. It will have a 6 in. by 3 in. working section and will operate at constant temperature and at stagnation pressures up to 200 lb. per square inch. It will be operated by high-pressure air supplied from ten torpedo air vessels by a petrol-driven air compressor. Other extra-mural work carried out at Sydney University includes the development of a water channel to explore the analogy between flow in a shallow water channel and supersonic flow; and the development of "boundary layer ramps" for delaying separation.

A high-speed flight recorder is under construction to facilitate flight tests. A section has been formed to provide and calibrate vibration measuring equipment; they have constructed an amplifier to drive a de Havilland moving-coil vibrator, and have supervised the assembly of a second oscillator and amplifier for exciting vibrations in structures under test. A system for the digital recording of static strains at 192 points in a structure, at a rate of 12·5 measurements per second, is being investigated. Other work on instrumentation includes the design of relay scaling, or frequency-dividing circuits; the construction of direct-current amplifiers; and the development of direct pressure recorders for flight tests, one of which, nearing completion, records on photographic paper by reflection from mirrors mounted on the pressure-sensitive elements; and equipment for measuring combined static and dynamic loads in fatigue testing.

HIGH-SPEED AERODYNAMICS.

It is hoped that the continuous-flow supersonic wind tunnel at the Salisbury laboratories, which will have a 15-in. square working section and will be supplied by compressors driven by a 4,000-h.p. motor, will be assembled by the middle of this year. The design of the second tunnel, of the intermittent blow-down type with a 4-ft. square working section, has not yet commenced; a pilot model, however, with a 6-in. square section, is being designed to try out some of the features of the large tunnel.

During the year, most of the difficulties in developing the rocket-boosted free flight test vehicles for research on wing shapes, engine air intakes and wing flutter, have been overcome, and a contract has been awarded to an aircraft company for the manufacture of components and assembly of the rounds. The rate of manufacture is sufficient to maintain a steady firing rate of 6 to 8 rockets a month.

TEST PLANTS FOR "AVON" JET ENGINES.

A NEW engine test plant has been installed recently at the works of the Standard Motor Company, Limited, Coventry, for testing Avon jet engines constructed by the Standard company in co-operation with the Avon designers, Messrs. Rolls-Royce Limited, Derby. The entire test-house installation has been supplied by Messrs. Heenan and Froude, Limited, Worcester, who have been commissioned also to supply test equipment for the Avon production programme to Messrs. Rolls-Royce Limited, and D. Napier and Son, Limited. This is the first occasion in which a bulk order has been placed with a single firm for complete jet-engine test plant.

During the second World War, the Standard Motor Company produced Bristol radial air-cooled piston engines under contract, and an engine test-house was installed for testing them. The

TEST PLANTS FOR "AVON" JET ENGINES.

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(*For Description, see Page* 588.)

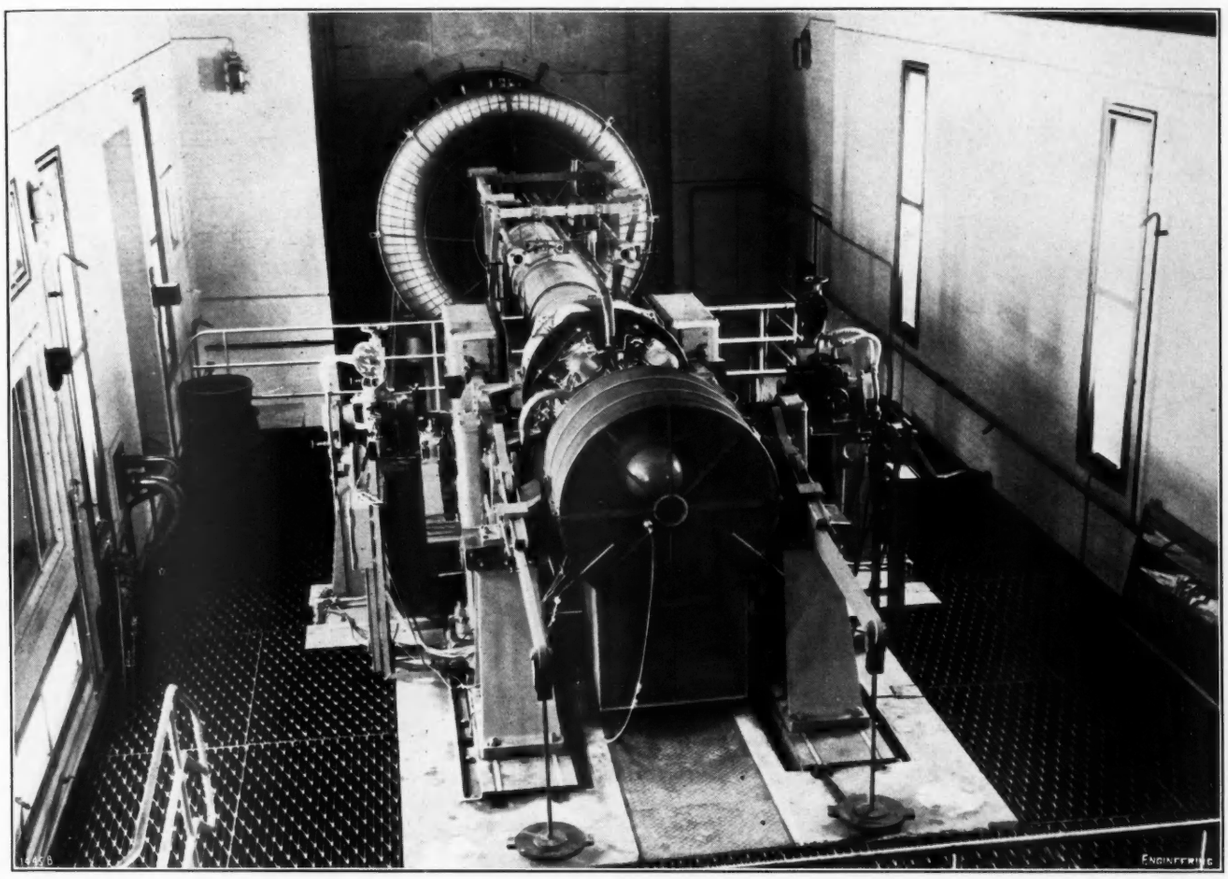

FIG. 2. ENGINE TEST STAND.

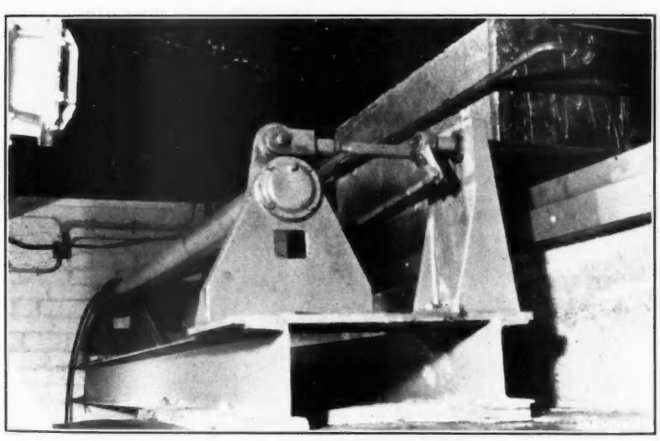

FIG. 3. PART OF LEVER MECHANISM.

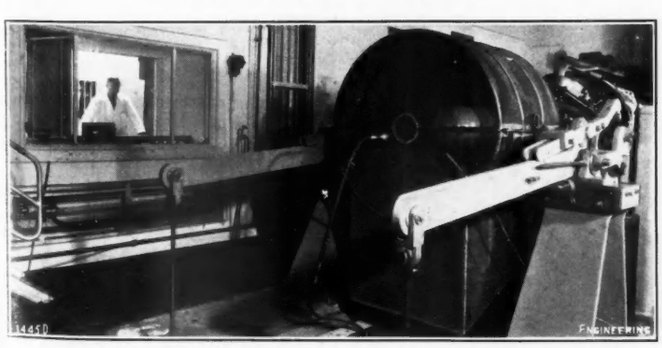

FIG. 4. TEST STAND, SHOWING CONTROL-ROOM WINDOW.

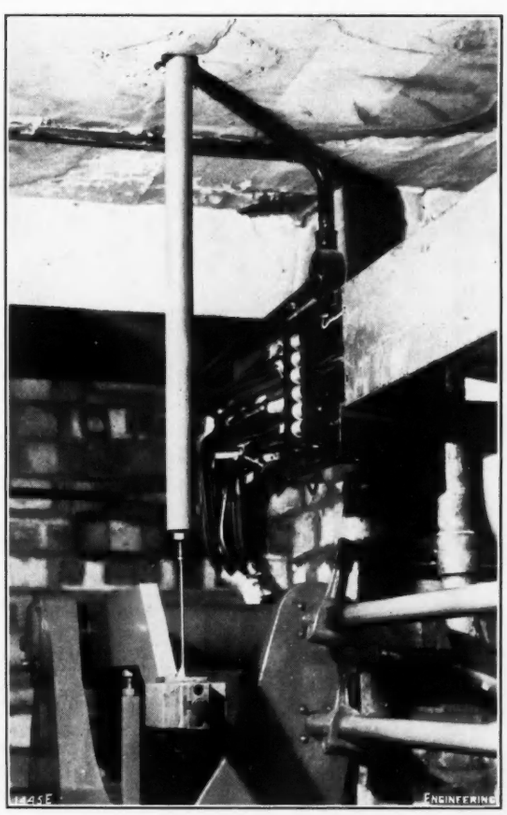

FIG. 5. PULL-ROD CONNECTION TO PENDULUM WEIGHER.

(*To face page* 588.)

TEST PLANTS FOR "AVON" JET ENGINES.

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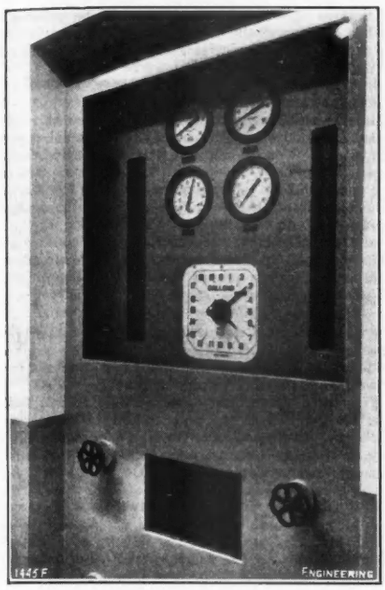

FIG. 6. FUEL MEASUREMENT CONSOLE.

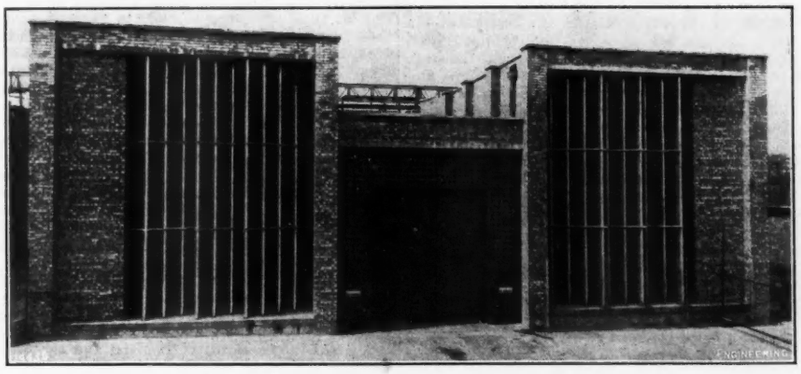

FIG. 7. TEST-HOUSE, SHOWING SPLITTER VANES.

same buildings are used to house the new jet-engine test plant, and the layout of the installation has been largely determined by this fact. Since the power developed by the piston engines on test was absorbed by propellers of large diameter, the nacelles for mounting them were some 10 ft. above floor level; the control room was raised accordingly. The same control-room position has been retained for the jet-engine plant, and the space below is utilised for the storage of batteries, carbon-dioxide bottles, etc. The building is of H-planform, housing two test stands with a common double control room. At one end, the space is roofed over to form a rigging shop.

TEST CRADLE AND THRUST WEIGHER.

The outside of the test-house is illustrated in Fig. 7, above. The thrust cradle for the jet engine is shown in Fig. 2, on Plate XVIII, and the control desk can be seen in Fig. 1, opposite. Figs. 3, 4, and 5, on Plate XVIII, show some details of the thrust-measuring linkages; and Fig. 6 shows the fuel measurement console. The thrust cradle, which is designed to be suitable for larger and more powerful engines than the Avon, consists of a strong channel-section framework to which the engine is attached by brackets. The framework is suspended from heavy cast-iron pedestals by steel strips which allow the engine to move freely in the axial direction, but which restrain sideways movement.

Since the hot exhaust gases may not always emerge from the jet pipe in a truly axial direction, each side of the cradle is connected to a system of thrust-resisting levers, the two systems being coupled together by a strong twist-shaft, thus resisting any tendency for the cradle to yaw. Part of the lever system is illustrated in Fig. 3, on Plate XVIII. The final lever is connected to a thrust-weighing machine by pull-rods; to reduce friction, they do not slide in bushes but are suspended from flexible steel strips. The ratio of the force on the weighing machine to the engine thrust is 1 to 75.

The thrust-weighing machine, an Avery pendulum weigher, is connected to the final pull-rod lever by a high-tensile steel link only $\frac{1}{16}$ in. in diameter, shown in Fig. 5, on Plate XVIII, which acts as a flexible connection so that the mechanism of the Avery machine is not strained by any possible misalignment. To check the accuracy of the readings, checking gear is provided by which any desired thrust can be imposed on the cradle, and the main weigher readings can be checked against the imposed thrust, which is known with great accuracy. The specification called for a high accuracy of thrust measurement—an error not exceeding 0·1 per cent. at maximum load. In practice, in a typical check test, a maximum error of 0·06 per cent. was obtained, with an average error of about 0·0225 per cent. For testing the engine auxiliary take-off drive, two small Froude dynamometers are fitted to each cradle, with Rotol special drive shafts. A small Heenan water cooler continuously cools and recirculates the heated water leaving the dynamometers.

FUEL SYSTEM.

The main storage tanks for each test stand, sunk in a pit outside the test-house buildings, each hold 12,000 gallons. Fuel is pumped to each test stand by Wayne centrifugal pumps driven by flameproof motors. Similar pumps are provided for unloading. Fuel-tank contents gauges, filters, recording flow meters and de-aerators were all supplied by the Wayne Tank and Pump Company, Limited, Wayne Works, Newlands Park, London, S.E.26, who subcontracted the piping to Messrs. Daly and Son, Coventry. In each test installation is a fuel cubicle, constructed in brick as part of the main building, containing a mild-steel structure carrying Rotameter fuel-flow meters, an Avery-Hardoll flow meter fitted with a timing unit, and a Brodie-Kent flow meter for measuring the flow of reheat fuel. The cubicle is fitted with two Negretti and Zambra dial-type mercury thermometers and transmitting pressure gauges, a Vokes filter, a hydrometer, and an electrically-operated magnetic stop-valve. Heat-resisting glass windows provide for observing the instruments. The fuel system also incorporates a fuel-reclaim tank and contents gauge.

All the operations and tests are carried out from the control room; normally, no personnel are allowed in the engine room while a test is in progress. The engine can be observed from the control room through a large double-glass window, seen in Fig. 4, on Plate XVIII. The control desk, illustrated in Fig. 1, houses the two engine control levers and various instruments. Where the piping and cables for the instruments pass through the wall into the engine room, they are packed with sound-insulating material in a wall-box. A steel-plate manifold is fitted on the engine cradle from which the permanent piping and wiring can be coupled to the engine to be tested.

TEST-HOUSE SERVICES.

Fumes are removed from the engine and control rooms, pump-house and battery rooms by a comprehensive system of fans and ducting. The fuel cubicles are fitted with extractor fans which draw air heated to 70 deg. C. continuously through the cubicles. The rigging shop, control room, etc., are warmed by suspended heat diffusers and high-level heating coils.

The electrical equipment includes main distribution boards and fuseboards, 24-volt and 96-volt batteries with rectifiers and relays for charging, Rotax starter panels and high-energy units for the torch igniters, together with solenoid valves, ignition relays, time switches, desk panels, warning lights and horns, booster coils, etc., and various control panels for the auxiliaries. Messrs. Lee, Beasley and Company, Limited, Coventry, were the sub-contractors for the electrical installation.

Fire protection is provided by a system of piping arranged to distribute carbon dioxide to strategic points in the engine rooms, fuel cubicles, battery rooms, and fuel pump house. When the system is flooded, by means of pull handles, automatic change-over switches shut off the fuel supply, switch off the fan motors of the ventilating plant, and sound an alarm. The fire-fighting equipment was supplied by the Pyrene Company, Limited, Great West-road, Brentford, Middlesex.

For handling the engines, a two-ton Morris travelling pulley block and runway are installed in the engine room, and a runway for a hoist is also provided in a diffuser exhaust chamber which forms part of the soundproofing.

The sound damping was installed by Cementation (Muffelite), Limited, 39, Victoria-street, London, S.W.1, using an exhaust-gas diffuser developed by the Bristol Aeroplane Company, Limited, and manufactured by Heenan and Froude, except for the flared inlet, which was sub-contracted to Messrs. Frederick Braby and Company, Limited, Bristol. The exhaust gases leaving the jet pipe are led into the inlet of a large steel diffuser, where part of the velocity energy is converted to pressure energy. A considerable volume of fresh cool air is entrained in the diffuser to reduce the gas temperature. At the end of the diffuser a large "basket" spreader is fitted to break up and spread out the gas stream before it emerges to the atmosphere. In the final outlet passage the gas and air mixture passes through sound-absorbing splitters. Similar splitters, seen in Fig. 7, are used at the air inlet to each engine room. For communication between quiet and noisy areas, specially-constructed doors are used. The roof and walls of the exhaust chamber are lined with felted mineral wool, held in position by corrugated aluminium sheeting.

In the Heenan and Froude plants for the Rolls-Royce and Napier companies, a different form of sound-proofing is specified, supplied by Horace W. Cullum and Company, Limited, Flowers-mews, London, N.19. Instead of passing through a diffuser and thence through vertical "splitters," the exhaust gases flow directly into a "Detuner" in which they are gradually expanded; this Detuner is constructed of sound-proofing materials, and is of circular cross-section with internal annuli. The layout of these test plants themselves is also different, since the engines are tested at ground-floor level, and the control room is in line with (and slightly above) the engine instead of at a high position on one side. The general construction is, however, substantially identical, apart from the above variations and those due to site considerations.

NOTES FROM THE INDUSTRIAL CENTRES.

SCOTLAND.

Future of Scottish Colliery Industry.—In Scotland, the past few years had been planning years so far as coal production was concerned, but the stage was getting nearer where new collieries and new projects would bear some fruit, said Dr. W. Reid, Scottish divisional chairman of the National Coal Board, speaking at the second annual conference of the Scottish Women's Advisory Committee on Solid Fuel in Glasgow on April 28. To achieve their target the division would require to find 12,000,000 tons of new coal output by 1960-65, but, he added, they were on the way to doing this. There were eight large new collieries under construction and six others were planned, or about to be planned.

Water-Supply in Doon Valley.—Proposals for a water-undertaking development in the Doon Valley area in Ayrshire to augment the supply to Dalmellington, were outlined on April 28 by Mr. Thomas Leslie, county engineer, in a report to Ayr County Council. The estimated cost of the work was 117,000*l*. From discussions with National Coal Board officials, it appeared, he said, that the water requirements at Pennyvenie and Beoch might be between 30,000 to 50,000 gallons daily. An adequate water supply would enable the Board to improve housing standards in these areas. The total future requirements in the Dalmellington district, allowing for supplies for other industries, were estimated at 500,000 gallons a day.

Gorebridge Water-Filtration Works.—A new water-filtration works opened on April 24 at Gorebridge, Midlothian, incorporates improved microstrainers, which are expected to play a big part in the export field. Mr. E. Bruce Ball, joint managing director of Glenfield and Kennedy, Ltd., Kilmarnock, said at a luncheon after the opening ceremony that the plant will handle 2,000,000 gallons a day, but machines were now being manufactured to deal with 320,000,000 gallons daily. He added that the process was unique and once it had been proved in Britain it was hoped to extend it overseas.

Settlement of the Blairnevis Collision.—As a result of a Supreme Court of Canada ruling announced on April 28, the Nisbet Shipping Company, Ltd. (managed and owned by George Nisbet & Co., Glasgow), will be entitled to recover damages from the Canadian Government of up to 38.92 dols. a ton as the amount of liability arising out of the collision, in 1945, of the Canadian frigate Orkney with the freighter Blairnevis, of 4,155 tons gross, owned by the Glasgow firm.

CLEVELAND AND THE NORTHERN COUNTIES.

Shipbuilding Activity on the Tyne.—May will be a poor month for Tyne ship launches; only one ship is scheduled to enter the water. This will be the 13,360 gross tons City of Durban, being built at Walker by Vickers-Armstrongs Ltd., for Ellerman Lines. The launching will bring the Tyne's output for the first five months of the year to nine vessels, aggregating more than 81,000 gross tons. In the corresponding period of last year there were seven launches, totalling about 58,000 tons. By the end of May, 13 ships making together 140,000 gross tons, will have been completed by Tyne shipyards. In the corresponding period of last year, 92,000 tons were completed. So far, this year, only three small vessels have been ordered on the Tyne. In the first four months of last year 195,000 tons deadweight capacity of shipping had been ordered from Tyne yards

North-East Coast Iron and Steel Production.—At the annual meeting, at Middlesbrough, of the No. 2 area of the Iron and Steel Trades Confederation, Mr. J. Senior, the divisional officer, reported that, in the past year, there had been an improvement in the production of steel ingots. In the early part of the year, there had been anxiety on account of short-time working, due to reduced ingot supplies and shortage of scrap. The position had been neutralised by better supplies of pig iron and more scrap. Pig-iron production in the North-East in 1951 had averaged 45,000 tons a week, but, in 1952, it had reached 50,000 tons. Mr. Senior said that when reorganisation now being carried out at several north-east works was completed, the area would become one of the highest producers of steel ingots in Great Britain.

Tyneside Trading Statistics.—Coal and coke shipments from the Tyne in March amounted to 793,179 tons, compared with 989,680 tons last year. For the first quarter of this year shipments totalled 2,221,032 tons, a decrease of 10·6 per cent. on 1952 and 32 per cent. less than 1938. The coal shipping figures for the Tyne for the first three months of last year were inflated owing to a strike of teemers at Blyth which led to much of Blyth's normal business being diverted to the Tyne. In the first quarter of this year, 424,294 tons were sent abroad, an increase of more than 40,000 tons on 1952. In the first two months of 1953, imports of general merchandise totalled 383,622 tons. The main items were iron ore, 104,057 tons; oil fuel and other oils, 101,855 tons; cement, 19,199 tons; grain, 46,739 tons; and pit props, 12,157 tons.

Extensions to Shipyard, Hebburn-on-Tyne.—Hawthorn, Leslie & Co. Ltd., Hebburn-on-Tyne, are completing extensions to another building berth to allow the construction of ships of 30,000 tons deadweight capacity. The yard already has one berth able to take ships of this size. Hawthorn, Leslie's have four ships of 31,000-32,000 tons on order.

Norwegian Factory Employees in England.—On May 3, fifteen non-manual employees from shipyard and cable and engineering works arrived in Newcastle to start on a fortnight's study tour of industrial plants and mines in the North of England and the London region. The group are touring a shipyard in Newcastle and a steelworks and a coal mine in the Sheffield area. During their stay in London, the Norwegians will visit the Ford Motor Works in Dagenham, a cable plant and a musical-instruments factory. Visits will also be made to the B.B.C., the Houses of Parliament, and other places of general interest, and the programme moreover, covers informal meetings with British employees. The Norwegian group is one of 48 groups of European operatives which, this year, received travel awards from Unesco for educational study tours within the European area. A total of around 900 manual and non-manual employees from twelve European countries will be taking part in the scheme, under which Unesco covers the inter-country fares while the beneficiary organisations and their hosts—or the participants themselves—pay for accommodation costs and incidental expenditure.

LANCASHIRE AND SOUTH YORKSHIRE.

Colliery Efficiency Committees.—Efficiency Committees are to be set up at each of the eight areas of the North-Eastern Division of the National Coal Board. Similar committees have already been established at virtually all Yorkshire pits. The Yorkshire Miner's President, Mr. J. R. A. Machen, states that the committees are helping to create a happier atmosphere in the Yorkshire coalfield by letting the men take some part in the running of the industry. They are getting down to problems at coal-face level and accomplishing much good work in settling difficulties on the spot and thus reducing the chances of disputes.

300-MW Power Station at Ferrybridge, Yorkshire.—The British Electricity Authority has received the consent of the Minister of Fuel and Power to establish a new section of the Ferrybridge power station, Yorkshire. This station, which will be known as Ferrybridge B, will have an installed capacity of 300 MW and will contain three 100-MW sets, each of which will be supplied from a 755,000-lb. boiler. There will also be three cooling towers, each with a capacity of 4,000,000 gallons of water per hour. The installed capacity of the existing station is 170 MW.

Colliery Fire-Fighting.—A replica of an underground pit shaft was built in the pit-yard of Rossington Colliery, near Doncaster, when the colliery fire-fighting competitions were held. Tests included crawling under air doors and over tubs to reach the seat of "fires." Men taking part were in full coal-face clothing, including helmets. The winners, who received prizes supplied by the National Coal Board, will go forward to the area finals to be held on May 30 at Woodlands.

Memorial to Sir Robert Hadfield.—A movement is afoot in Sheffield to provide a public memorial to the late Sir Robert Hadfield, Bt., the distinguished metallurgist, scientist and inventor, who, in his lifetime, did a great deal to raise Sheffield to its leading position in the steel world. The movement is being sponsored by the Master Cutler, Sir Harold West, So far, the only memorial to Sir Robert in Sheffield is a plaque on the house where he was born.

THE MIDLANDS.

The Re-Siting of Birmingham Industry.—The Birmingham City Council have been promised permission to spend 350,000*l*. on the first phase of the City development plan. Some of the older parts of the City are scheduled for complete redevelopment, which will involve the demolition of a number of factories of varying sizes, as well as houses and commercial premises. Firms owning factories affected by by the plan will be able to obtain licences and spend capital to erect new buildings. Small firms, not able to finance their own re-building, will be catered for by the erection of the Council of multi-storey factories on the "flatted" principle, with facilities for renting as much accommodation as may be required.

Atmospheric Pollution at Kidderminster.—The Public Health Committee of the Kidderminster (Worcestershire) Borough Council have reported that atmospheric pollution in the town is responsible for the deposition of 20 tons of solid matter per square mile per annum. This is twice as heavy as in the towns of Stourbridge and Halesowen, which are of comparable size, and are on the fringe of the Black-Country industrial area. The local authority are collecting evidence to support possible future action, and have already had photographs taken of the premises of the principal offenders.

Re-Opening of Brickworks.—The Premier Brick Co's works at Parkfield, one of the two remaining brickworks in Wolverhampton, have been re-opened after being almost completely idle since 1941. The works, which have been acquired by K. E. Millard & Co., Ltd., public-works and building contractors, of Oldbury, Worcestershire, were re-opened with an output of 50,000 bricks a week, but this figure is to be increased progressively to 200,000.

Underground Gasification of Coal.—The experimental work on the underground gasification of coal, which is being carried out at Rock, near Bewdley, Worcestershire, by the Ministry of Fuel and Power, is to be extended. It is proposed to increase the site area by 2½ acres.

Saturday Shifts at the Pits.—Most branches in the Nottingham area of the National Union of Mineworkers have agreed to continue, during the summer, the voluntary working of the Saturday shift. Under the national agreement they have a right to refuse Saturday work during the summer. If a branch decides not to work on Saturday the pit manager may call for a ballot of the members.

SOUTH-WEST ENGLAND AND SOUTH WALES.

Unemployment in Wales.—The number of people registered as wholly unemployed in most areas in Wales had fallen by mid-March with the revival of activity in the seasonal trades, the Minister of Labour has reported to the Welsh Board for Industry. There was a fall over the month of 462 in the number of persons temporarily stopped but short-time working was still extensive in some of the metal manufacturing industries such as tin-plate, steel sheet and light alloys. On March 16 there were 31,392 registered as unemployed in Wales, a decrease of 2,109 since February 16. Of this number 26,045 were wholly unemployed and 5,347 were registered as temporarily stopped. It is announced that three productivity teams are to be set up for Wales by the Welsh Board for Industry, one at Wrexham for the north, one at Swansea for the west, and one at Cardiff for the rest of Wales.

Irish Anthracite Exports.—Eire, which has only recently entered the export market for anthracite has now made her first sale to the Continent, one of about 300 tons to buyers in Holland. As recorded last week, limited quantities of this coal, which is said to be the equal of best Welsh in quality, have been received by consumers in the South-Western English counties.

Exports of Welsh Steel to the United States.—Many thousands of tons of United States steel have been imported through the South-Wales docks to help meet the urgent post-war needs, but, recently, a shipment has been made in the reverse direction. The steamer Manchester Division has loaded 1,000 tons of steel coils at Swansea docks for America. This represents a new trade for the port. The coils were manufactured at the Abbey works of the Steel Company of Wales Ltd.

Closure of Tin-Plate Works.—Three tin-plate works owned by the Steel Company of Wales Ltd., at Llanelly, Pontardawe and Gorseinon, closed temporarily on May 4. The step has been caused through lack of orders. In a statement, the company says that they have decided, instead of putting all their works on short-time working, to concentrate production in certain works on a full-time basis so that continuity of operations in these works can be maintained.

NOTICES OF MEETINGS.

IT is requested that particulars for insertion in this column shall reach the Editor not later than Monday morning in the week preceding the date of the meeting.

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS.—*Central London Branch:* Monday, May 11, 6.45 p.m., St. Ermin's Hotel, Caxton-street, Westminster, S.W.1. "Development of Clocks," by Mr. C. W. Levey. *Bradford Branch:* Wednesday, May 13, 7.30 p.m., Midland Hotel, Bradford. "Air Conditioning," by Mr. J. Rose.

INCORPORATED PLANT ENGINEERS.—*Dundee Branch:* Monday, May 11, 7.30 p.m., Mathers Hotel, Dundee. "Textile Machinery," by Mr. Robert Baird. *East Lancashire Branch:* Tuesday, May 12, 7.15 p.m., Engineers' Club, Albert-square, Manchester. Film Display. *East Midlands Branch:* Wednesday, May 13, 7 p.m., Welbeck Hotel, Nottingham. "Industrial Applications of the Thickness Gauge" by Mr. R. Y. Parry. *Newcastle-upon-Tyne Branch:* Thursday, May 14, 7.30 p.m., Roadway House, Oxford-street, Newcastle-upon-Tyne. "Electrical-Fuel Injection Equipment Applicable to Heavy Goods Vehicles and Contractors' Plant," by Mr. H. J. Stoneham. *Liverpool Branch:* Monday, May 18, 7.15 p.m., Radiant House, Bold-street, Liverpool. "Report on Visit of Plant Maintenance Team to United States," by Mr. Colin Troup. *Hertfordshire Discussion Group:* Tuesday, May 19, 7.30 p.m., Peahen Hotel, St. Albans. "Sound Control in Industry," by Mr. W. A. Hines.

INSTITUTION OF CIVIL ENGINEERS.—*Works Construction Division:* Tuesday, May 12, 5.30 p.m., Great George-street, Westminster, S.W.1. "Construction of Tignes Dam and Malgovert Tunnel," by Mr. J. Pelletier. *Maritime and Waterways Engineering Division:* Thursday, May 14, 5.30 p.m., Great George-street, Westminster, S.W.1. Lecture on "Echo Sounding in Relation to Modern Harbour and Coastal Surveys," by Commander D. H. Macmillan. *Institution:* Tuesday, May 19, 5.30 p.m., Great George-street, Westminster, S.W.1. James Forrest Lecture on "The Impact of Statistics on Civil Engineering," by Professor H. Levy.

INSTITUTE OF MARINE ENGINEERS.—Tuesday, May 12, 5.30 p.m., 85, Minories, E.C.3. "Service Performance of Boiler Brickwork: The Causes and Extent of Wastage," by Mr. B. Taylor and Mr. H. Booth.

ILLUMINATING ENGINEERING SOCIETY.—Tuesday, May 12, 6 p.m., Royal Society of Arts, John Adam-street, Adelphi, W.C.2. Annual General Meeting. "Lighting in Australia and Europe," by Mr. D. C. B. Maclurcan.

INSTITUTION OF PRODUCTION ENGINEERS.—*Birmingham Graduate Section:* Tuesday, May 12, 7 p.m., James Watt Memorial Institute, Great Charles-street, Birmingham. "Mechanised Inspection." by Mr. J. Loxham. *Wolverhampton Graduate Section:* Tuesday, May 12, 7.30 p.m., Star and Garter Royal Hotel, Victoria-street, Wolverhampton. Brains Trust Meeting on "Production Engineering Problems." *Stoke-on-Trent Section:* Friday, May 15, 7.30 p.m., Building Department, North Staffordshire Technical College, Cauldon-place, Shelton, Stoke-on-Trent. "Education for Industrial Management," by Professor T. U. Matthew. *Sheffield Graduate Section:* Tuesday, May 19, 6.30 p.m., Royal Victoria Station Hotel, Sheffield. "The Application of Tungsten-Carbide Tooling," by Mr. A. Brooke.

ROYAL SOCIETY OF ARTS.—Wednesday, May 13, 2.30 p.m., John Adam-street, Adelphi, W.C.2. Trueman Wood Lecture on "Training for Science and Technology," by Sir Richard Southwell, F.R.S.

ROYAL STATISTICAL SOCIETY.—*Research Section:* Wednesday, May 13, 5.15 p.m., London School of Hygiene and Tropical Medicine, Keppel-street, Gower-street, W.C.1. "New Light on the Correlation Coefficient and Its Transforms," by Professor Harold Hotelling. *Study Section:* Tuesday, May 19, 6 p.m., Lighting Service Bureau, 2, Savoy-hill, W.C.2. "Sample Surveys and Their Use for Administrative Purposes," by Mr. L. Moss.

INSTITUTE OF PETROLEUM.—Wednesday, May 13, 5.30 p.m., Manson House, 26, Portland-place, W.1. "Mechanical Handling in the Petroleum Industry," by Mr. E. A. Reynolds and Mr. V. F. H. Samson.

INSTITUTION OF ELECTRICAL ENGINEERS.—*Radio Section:* Wednesday, May 13, 5.30 p.m., Savoy-place, Victoria-embankment, W.C.2. Section Annual Lecture on "Recent Work in France on New Types of Valve for the Highest Radio Frequencies," by Dr. R. Warnecke and Mr. P. Guenard. *Institution:* Thursday, May 14, 5.30 p.m., Savoy-place, Victoria-embankment, W.C.2. Annual General Meeting. (For corporate members and Associates only.) *London Students' Section:* Monday, May 18, 7 p.m., Savoy-place, Victoria-embankment, W.C.2. Annual General Meeting and Film Display. *Measurements Section:* Tuesday, May 19, 5.30 p.m., Savoy-place, Victoria-embankment, W.C.2. Section Annual Lecture on "Measurement with the Flying-Spot Microscope," by Professor J. Z. Young, F.R.S. (Postponed from May 5.) *Education Discussion Circle:* Tuesday, May 19, 6 p.m., Savoy-place, Victoria-embankment, W.C.2. Questions Night. *Supply Section:* Wednesday, May 20, 5.30 p.m., Savoy-place, Victoria-embankment, W.C.2. Lecture on "The Utilisation of Solar Energy," by Dr. E. C. Bullard, F.R.S.

SOCIETY OF CHEMICAL INDUSTRY.—*Corrosion Group:* Wednesday, May 13, 6.30 p.m., Chemical Society's Apartments, Burlington House, Piccadilly, W.1. Annual General Meeting. Chairman's Address on "Corrosion: A Field for Action." by Dr. W. H. J. Vernon.

INSTITUTION OF STRUCTURAL ENGINEERS.—*Wales and Monmouthshire Branch:* Wednesday, May 13, 6.30 p.m., Mackworth Hotel, Swansea. Annual General Meeting. *Institution:* Thursday, May 14, 6 p.m., 11, Upper Belgrave-street, S.W.1. "The Structural Aspect of Power-Station Design in South Africa," by Mr. G. M. Frost. Thursday, May 21, 5.30 p.m., Royal Technical College, George-street, Glasgow. Annual General Meeting of the Institution. "Engineering Aspects of the New Atomic Research Extension, University of Glasgow," by Mr. D. M. Hamilton and Mr. J. Hardie Glover.

INSTITUTION OF SANITARY ENGINEERS and INSTITUTION OF HIGHWAY ENGINEERS.—Thursday, May 14, 6 p.m., Caxton Hall, Victoria-street, Westminster, S.W.1. Joint Meeting. Discussion on "Re-Instatement of Pipe Trenches: Public Utilities Street Works Act, 1950," to be opened by Lieut.-Col. S. M. Lovell and Mr. N. J. Tatman.

ROYAL INSTITUTION.—Friday, May 15, 9 p.m., 21, Albemarle-street, W.1. "Observational Evidence for an Expanding Universe," by Dr. Edwin Hubble.

ROYAL METEOROLOGICAL SOCIETY.—Wednesday, May 20, 5 p.m., 49, Cromwell-road, South Kensington, S.W.7. (i) "Annual Recurrences in Edinburgh Temperature," by Mr. D. H. McIntosh; (ii) "Climatic Fluctuations in the Greenland and Norwegian Seas," by Mr. P. R. Brown; and (iii) "The Mean Temperature of Central England, 1698 to 1952," by Mr. G. Manley.

ROYAL AERONAUTICAL SOCIETY and PHYSICAL SOCIETY (*Acoustics Group*).—Thursday, May 21, 10 a.m., 2.30 p.m. and 4.30 p.m., Institution of Mechanical Engineers, Storey's-gate, St. James's Park, S.W.1. Joint All-Day Meeting on "Aeronautical Acoustics: In Particular Jet Noise." For programme, see page 580.

ROYAL MICROSCOPICAL SOCIETY.—Wednesday, May 27, 5.30 p.m., Tavistock House South, Tavistock-square, W.C.1. (i) "High-Speed Automatic Counting of Microscopic Particles—The Flying-Spot Microscope," by Mr. D. Causley; and (ii) Demonstration of the Permanent-Magnet Electron Microscope, by Mr. R. W. Horne.

ADMIRALTY FUELS AND LUBRICANTS ADVISORY COMMITTEE.

AT the end of 1950 an Admiralty Oil Quality Committee was set up, firstly to review questions of the characteristics and nature of fuels and lubricants for the Royal Navy, and secondly to advise whether a permanent committee should be established. Upon the recommendation that such a permanent committee be formed, an Admiralty Fuels and Lubricants Advisory Committee, under the chairmanship of the Hon. R. C. Geddes, has now been established. The committee comprises Professor F. H. Garner, O.B.E., of the University of Birmingham; Dr. C. M. Cawley, O.B.E., of the Department of Scientific and Industrial Research; Mr. H. S. Gibson, C.B.E., President, Institute of Petroleum; Mr. I. G. Barr-Adams, past president, National Lubricating-Oil and Grease Federation; Lt.-Col. S. J. M. Auld, O.B.E., M.C., petroleum consultant; Mr. B. G. Banks, Trinidad Leaseholds Limited; Mr. J. Dotchin and Mr. D. B. Vale, of the Shell Petroleum Company; Mr. C. V. Hill and Mr. C. H. W. Smith, of the Anglo Iranian Oil Company; Mr. H. F. Jones, M.C., of the British Mexican Petroleum Company; Mr. W. Kay, of the Esso Petroleum Company, and Mr. C. Lawrie of the Vacuum Oil Company. In addition, representatives from the Ministry of Fuel and Power and from various Admiralty departments are to serve on the committee, which has also appointed a Fuels Technical Sub-Committee under the chairmanship of Professor F. H. Garner, and a Lubricants Technical Sub-Committee under the chairmanship of Dr. C. M. Cawley. Apart from members of the main committee serving on these sub-committees, the following representatives of various oil companies have also been appointed: Mr. A. E. Gerty, Mr. C. W. G. Martin and Mr. F. G. Richards, to the Fuels Sub-Committee and Mr. R. W. L. Fox, Mr. N. G. Gullick, Mr. A. R. Stark, Mr. R. S. Teale, Mr. G. H. Thornley, Mr. E. H. Wild and Mr. J. M. Wilson, to the Lubricants Sub-Committee.

PERSONAL.

SIR LAWRENCE BRAGG, F.R.S., who has been Cavendish Professor of Experimental Physics at the University of Cambridge since 1938, has been appointed Fullerian Professor of Chemistry, resident professor, and director of the laboratories of the Royal Institution, Albemarle street, London, W.1.

SIR ROYDON DASH, D.F.C., F.R.I.C.S., has been proposed by the Minister of Housing and Local Government to succeed SIR THOMAS BENNETT, C.B.E., F.R.I.B.A., as chairman of the Stevenage New Town Development Corporation.

SIR ARTHUR SMOUT, F.R.I.C., F.I.M., J.P., past-president of the Institute of Metals, 4, Grosvenor-gardens, London, S.W.1, has been elected a Fellow of the Institute. The number of Fellows is limited to 12.

LT.-COL. T. EUSTACE SMITH, joint managing director, Smith's Dock Co. Ltd., has been re-elected President of the North-East Coast Institution of Engineers and Shipbuilders, Bolbec Hall, Newcastle-upon-Tyne, 1.

MR. DAVID P. RANSOME, M.I.Mech.E., M.I.P.E., has been elected President of the Institution of British Agricultural Engineers, 24, Portland-place, London, W.1.

The honorary degree of Doctor of Science is being conferred upon the eminent French engineer, MR. EUGÈNE FREYSSINET, by the University of Leeds, on May 14.

DR. W. IDRIS JONES has been elected President of the Institute of Fuel, 18, Devonshire-street, Portland-place, London, W.1, for the 1953-54 session. He will succeed DR. G. E. FOXWELL in October.

WING COMMANDER R. STANFORD-TUCK, D.S.O., D.F.C., has been released by Marconi's Wireless Telegraph Co. Ltd., to join the aircraft division of the English Electric Co., Ltd.

MR. G. N. VANSITTART has relinquished the office of chairman of Vauxhall Motors Ltd., as from June 1, when he will take up the chairmanship of General Motors Ltd., in succession to MR. W. E. HILL. SIR CHARLES BARTLETT is to be the new chairman of Vauxhall Motors and Mr. W. E. Hill succeeds Sir Charles as managing director of that company.

MR. A. C. BOSSOM, M.P., has been made an honorary Fellow of University College London. SIR JOHN BLAKE, Comptroller-General of Patents, Designs and Trade Marks has been made a Fellow.

MR. JAMES GRAY, C.B.E., M.I.C.E., M.Inst.N.A., retired from the position of superintendent engineer of the Union-Castle Mail Steamship Co. Ltd., 3, Fenchurch-street, London, E.C.3, on April 30, after 35¼ years of service with the company. MR. E. C. HOLL, M.Inst.N.A., has been appointed superintendent engineer and MR. G. MCNEE and MR. J. MCNAUGHT assistant superintendent engineers.

MR. G. H. THORNLEY, M.Sc.(Tech.), F.Inst.Pet., has been elected a vice-president of the Institute of Petroleum.

MAJOR C. J. STEWART, C.B., O.B.E., F.R.Ae.S., Wh.Ex., M.I.Mech.E., and MR. F. H. CAREY, have been elected directors of Dowty Fuel Systems Ltd., Cheltenham.

MR. CHARLES GARDNER is to take up an appointment, at the end of the summer, as assistant to Mr. G. R. Edwards, general manager of the aircraft division of Vickers-Armstrongs Ltd., Vickers House, Broadway, London, S.W.1.

MR. W. H. KETCHELL has been appointed resident director of Harry Ferguson of India Ltd., 4, Cunningham-road, Bangalore, in succession to MR. R. C. HEATH.

MR. C. S. BRAND, MR. A. F. HAXTON, M.I.C.E., and MR. H. C. THOMSON, C.A., have been elected directors of Charles Brand & Son, Ltd., 25-27, Charles II-street, Haymarket, London, S.W.1.

MR. N. L. GOODCHILD has relinquished his appointment as raw materials officer of the British Iron and Steel Federation, Steel House, Tothill-street, London, S.W.1.

MR. R. G. MCCOY, B.Sc., A.F.R.Ae.S., has been appointed deputy service manager of the de Havilland Aircraft Co. Ltd., Hatfield, Hertfordshire.

F. A. HUGHES & CO. LTD. and the WESTINGHOUSE BRAKE AND SIGNAL CO., LTD., are pooling their experience in cathodic protection methods of corrosion prevention into the GUARDION SERVICE. Further particulars are obtainable from F. A. Hughes & Co. Ltd., Cathodic Protection Division, Bath House, 82, Piccadilly, W.1.

The interests, in South Africa, of LEYLAND MOTORS LTD. and ALBION MOTORS LTD. are to be amalgamated and a new company, to be known as LEYLAND-ALBION (AFRICA) LTD., will be officially registered on October 1.

DECCA RADAR LTD. and THE DECCA NAVIGATOR CO. LTD. have moved their Scottish office to larger premises at 67, Blythswood-street, Glasgow, C.2. (Telephone: City 6457/8.)

FLARE STACKS FOR BRITISH OIL REFINERIES.

BRITISH INSULATED CALLENDER'S CONSTRUCTION CO., LTD., LONDON.

(*For Description, see Page* 598.)

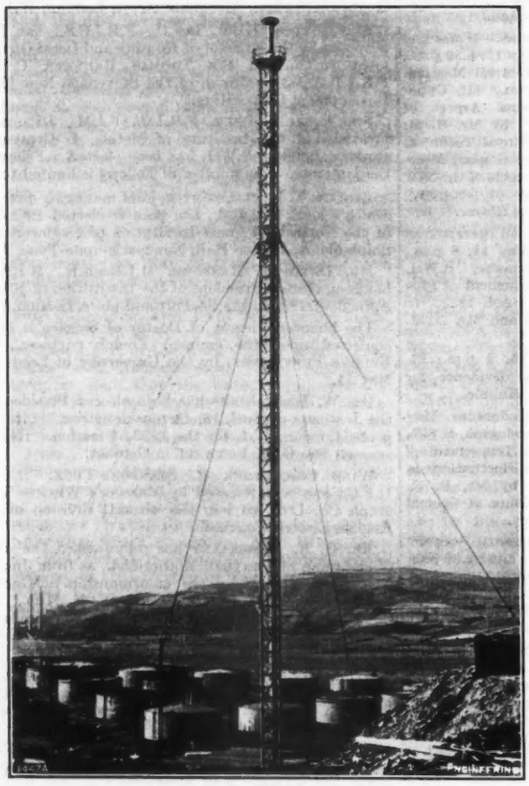

FIG. 1. STACK AT LLANDARCY.

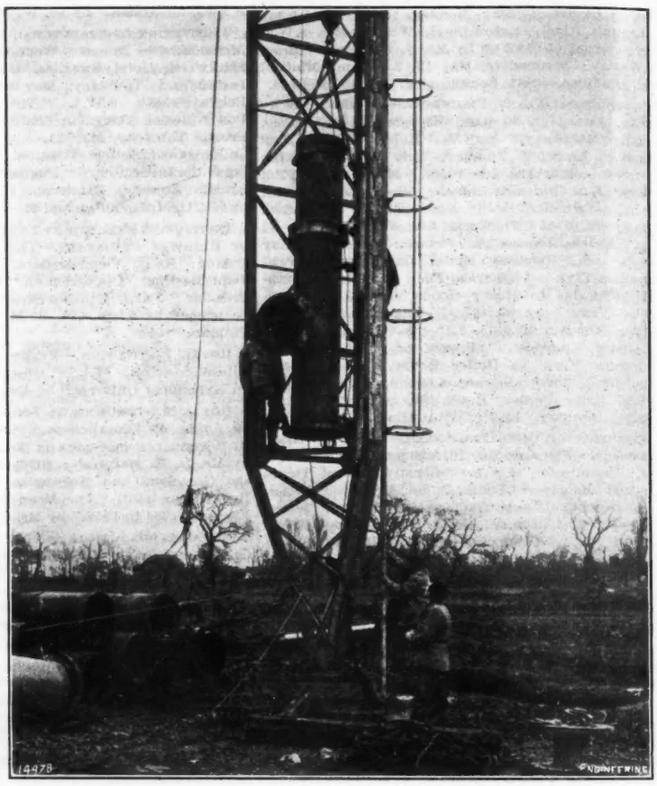

FIG. 2. FOOT OF MAST AND STACK.

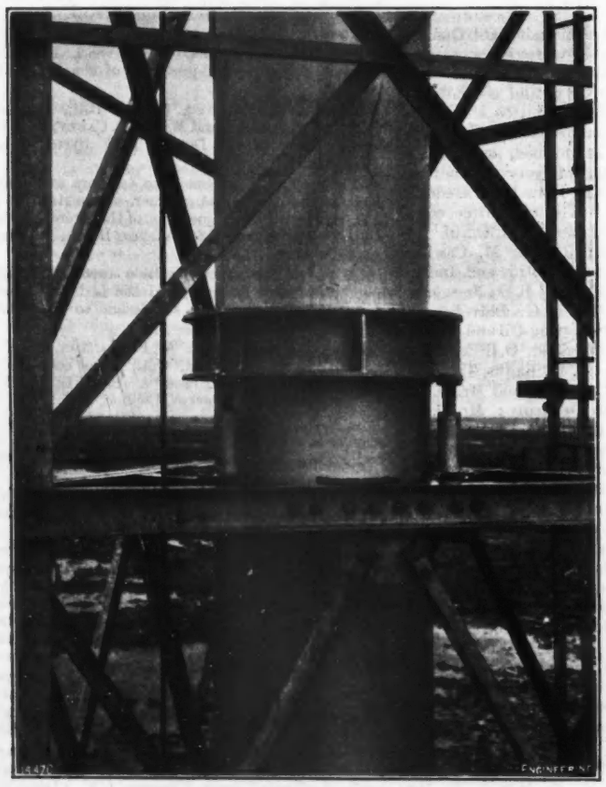

FIG. 3. SUPPORT FOR STACK DURING ERECTION.

FIG. 4. FLARE TIP.

ENGINEERING

35 & 36, BEDFORD STREET, STRAND, LONDON, W.C.2.

Registered at the General Post Office as a Newspaper.

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For Canada	£5 5 0

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ADVERTISEMENT RATES.

Terms for displayed advertisements can be obtained on application to the Manager. The pages are 12 in. deep and 9 in. wide, divisible into four columns 2¼ in. wide. Serial advertisements will be inserted with all practicable regularity, but absolute regularity cannot be guaranteed.

The charge for advertisements classified under the headings of "Appointments Open," "Situations Wanted," "Tenders," etc., is 10*s.* for the first four lines or under, and 2*s.* 6*d.* per line up to one inch. The line averages six words and when an advertisement measures an inch or more, the charge is 30*s.* per inch. If use is made of a box number the extra charge is 1*s.* per insertion, with the exception of advertisements appearing under "Situations Wanted." Series discounts for all classified advertisements can be obtained at the following rates:—5 per cent. for six; 12½ per cent. for thirteen; 25 per cent. for twenty-six; and 33⅓ per cent. for fifty-two insertions.

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Classified advertisements intended for insertion in the current week's issue must be received not later than first post Monday.

"Copy" instructions and alterations to standing advertisements for display announcements must be received 16 days previous to the date of publication, otherwise it may be impossible to submit proofs for approval.

The Proprietors will not hold themselves responsible for advertisers' blocks left in their possession for more than two years.

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ENGINEERING

FRIDAY, MAY 8, 1953.

VOL. 175. No. 4554.

AN INDEX OF PROSPERITY.

THE shipbuilding, motor-vehicle, steel, electricity-supply, office-equipment, container and building industries, as well as mechanical engineering generally, come in for some friendly prodding in a report issued this week by the Economic Commission for Europe. By studying production and consumption trends in "flat products"—plates, sheets, tinplate, hoop and strip—the report illuminates the significance of a class of semi-finished material which is as good an index of prosperity as can be found. It is shown, for example, that in recent years the much higher rate of increase in the production of thin flat products in the United States than in Europe is related directly to the relative standards of living, and it is argued that there is a great opportunity in Europes for adopting designs and production techniques which take advantage of the overall economy of using the products of the continuous wide-strip mill.

By specifying sheet or plate for jobs which might be made of steel in other forms, the designer ensures, unwittingly sometimes, that certain of the features desired in the end product are formed as early as possible in the chain of processes which start with the ore; that is to say, they are formed at the stage where it is cheapest to form them. Thus, for example, a high surface finish, which is generally more expensive the later it is imparted, is obtained economically on steel strip passing through a mill. Tolerances in thickness, which could only be obtained by relatively expensive machining at a later stage in production, are likewise readily controlled in the mill, and metallurgical homogeneity is ensured to meet the requirements of different users. Moreover, since these qualities are provided in an intermediate product like steel sheet, pressing, stamping, drilling and similar operations are economically carried out, and the scope for mass-production methods is correspondingly enlarged.

The appropriateness of sheet steel to mass-production methods explains to some extent the pronounced difference between the growth of production of sheets in the United States in the past two decades compared with the growth in Western Europe: a four-fold increase as against an increase of only one-third. The new continuous strip mills laid down in Western Europe in recent years are beginning to have effect, but they will have a long way to go before they catch up with their American counterparts, and the European engineering industry must become more alive to the technical potentialities of flat products if supply and demand are to remain in step. The difference in American and European trends is shown by the relative proportions of total steel consumption which are accounted for by flat products: in Western Europe the figure is now 41 per cent., but this is lower than the 1925 figure in the United States, where the proportion has now risen to nearly 60 per cent.

Comparisons of this kind—to which we have become accustomed since the war—usually grossly over-simplify the picture; they can be instructive, provided they are qualified by consideration of other factors involved. Thus a nation's consumption of thin flat products is a rough index of its standard of living. Steel sheet is used extensively in motor-cars, kitchen equipment and many of those mechanical servants which start as luxuries and become necessities in a few generations. A tribute is paid in the report to the American steel companies which had the foresight and courage to regard the continuous wide-strip mill as "a lever with which to raise production, consumption, and thus the standard of living, to new levels." For a time there was serious excess capacity in the United States, but eventually the demand grew to proportions which exceeded original expectations. This growth was stimulated not so much by normal publicity methods as by co-operative efforts of steel producers and users to evolve ways and means of increasing the use of flat products: "the steel producer and the engineer, representing the potential consumer, sit down together and work out how flat products can be used in a particular application."

Trends in the motor-car industry are examined in detail. Among the factors considered are the use of stressed-skin construction, the relationship between income levels and the number of inhabitants per vehicle, the influence of the geographical character of a country and the availability of alternative forms of transport, the fiscal policy of governments, and the effect of the price, quality and design of motor-cars. A study of the history of motor-car production policy in Western Europe leads to the conclusion that there is scope for the mass-production of three types of car: a small, cheap and popular car designed primarily for Europe, but also likely to sell in overseas markets where there are good road systems; a larger, more powerful and rugged utility model, mainly for less-developed countries with primitive road systems; and a luxury mass-produced car of adequate size and performance, capable of competing in third markets with the standard American passenger car. The report acknowledges the fact that some steps have been taken in this direction. The three recommended classes of car are exemplified to some extent by, firstly, the 2-h.p. Citroën and the Volks

wagen; secondly—to meet the need for a car which is the natural descendant of the Model T Ford—the Land Rover, the Austin Champ, and the 2-h.p. Citroën (regarded as a smaller version of this class); and, thirdly, the Jaguar Mark VII, which is said to compete seriously with the standard American car in the Chevrolet or even the Buick category. The adoption of an expansionist policy for the industry, by governments and the industry itself, is considered to be decisive, but it would be useful to hear the views of the motor-car manufacturers, who cannot fairly be accused of lethargy and who are sufficiently numerous and varied in their outlook not to have overlooked the possibility of satisfying the needs of customers.

If the motor-car industry can be regarded as amenable to encouragement and expansionist policy, the shipbuilding industry, the report recognises, depends almost wholly on factors outside its control. The demand for new ships is determined by the volume of international trade and the direction and nature of such trade, though an accelerated scrapping programme, carried out in conjunction with shipowners and other interested parties, is recommended as being beneficial. A rough calculation of world tonnages, now and in the future, shows that there is likely to be a considerable replacement demand in the years following 1956 for passenger, cargo and tramp ships, especially when allowance is made for the probable need to replace ships which were constructed by mass-production methods during the war. The production of containers, on the other hand, like the production of motor-cars, is closely related to personal incomes, as well as on the relative cost of tinned foods as compared with fresh food. The demand for tinned food is not likely to increase as rapidly in Europe as in the United States, though there is a definite trend in favour of it. The container industry, it is felt, can play its part by modernisation and specialisation, gaining, at the same time, from the reduction in the cost of steel produced in modern mills. The demand for containers is expected to outstrip production.

Railways, electric power, office equipment, building, durable consumer goods, and general mechanical engineering are considered also, but the key to this revealing study is in the statement that "prospects for heavy flats are largely dependent on investment and for thin flats on marginal consumer expenditure." If the plant required for rolling sheet and plate were relatively inexpensive, the problem facing the industry in Europe would be much less serious. But it is expensive; it is capital investment on a large scale, and consequently, if demand ever falls substantially below capacity, it will be necessary not only to reduce employment but also to shut down the furnaces and mills which represent the invested labour of former years. The proportion of its labour which a nation puts into capital works tends to rise as the standard of living rises, but it becomes more than ever necessary to ensure that the remaining available labour, engaged largely on producing consumer goods, is fully utilised. Modern technology has created no greater problem than that of deciding how much shall be spent on capital investment, and on what works it shall be expended. The precarious balance can only be maintained by concerted action of an almost ideally high order, but it should not be completely beyond realisation. Engineers may take a cue from this report* by following up its suggestions for a wider use of those flat, but potentially various, products of the strip mills.

* *The European Steel Industry and the Wide-Strip Mill.* Prepared by the Industry Division, Economic Commission for Europe. Publication No. 1953. II. E.6, United Nations, Geneva. Obtainable from H.M. Stationery Office, London, and United Nations sales agents throughout the world. [Price 7*s.* 6*d.*, 1 dol., 4 Swiss francs, and equivalents.]

THE NATIONAL BUREAU OF STANDARDS.

In the report of the National Bureau of Standards for the year 1951, there is a short section entitled "Battery Additives." In this, it is stated that investigations carried out with "a wide variety of commercial additives consisting of combinations of magnesium and sodium sulfates in various stages of hydration," which are claimed to rejuvenate "dead" batteries, showed that they "in fact have no effect on battery life or performance." The National Bureau of Standards operates under the direction of the United States Department of Commerce, and this statement about battery additives has had the remarkable result that, "because of the Bureau's handling of tests on . . . a chemical supposed to put new life into old auto batteries," the Secretary of Commerce has accepted the resignation of Dr. A. V. Astin, the Director of the Bureau.

The reason for this serious step is that the Senate Small Business Committee, after considering the matter, has charged the Bureau with "prejudice and haste." From information issued by Consumers' Research Inc. of Washington, New Jersey, it appears that tests with the particular additive, which has been the cause of the controversy, were also carried out at the Massachusetts Institute of Technology, which reported that the additive had an effect on the behaviour of a lead-acid battery in certain limited aspects. It is stated that this opinion in no way conflicts with the report of the Bureau of Standards, as that organisation was concerned with the effect of the additive on storage batteries under conditions of normal use.

It would be neither safe, nor seemly, to comment on the merits of the charge against the Bureau without much fuller details about the whole matter than are available, but it certainly calls for some general reflections. The Senate Small Business Committee is clearly a political body, and although it may, or may not, contain members with scientific attainments, as a body it certainly cannot claim impartial scientific status. No one is likely to claim that the Bureau of Standards, or its counterpart in this country, the National Physical Laboratory, is incapable of making a mistake, and although political authorities may be justified in criticising general policy, direct interference in the detail conduct of individual researches, if it became a practice, would undermine the scientific integrity of the whole organisation. Scientific truth cannot be clearly observed if attention must at the same time be directed to the political, or commercial, reactions to the conclusions to which it may lead. Fortunately, no event, comparable to the resignation of Dr. Astin, is on record in the annals of scientific research in this country, but unfavourable commercial reactions to reports of investigations carried out by the Department of Scientific and Industrial Research are not unknown. They have not resulted in anything more serious than somewhat acrimonious argument.

The resignation of Dr. Astin took place in March of this year, so that it is not mentioned in the report of the Bureau for 1952; there is also no mention of battery additives. The field covered by the Bureau of Standards is broadly equivalent to that of the National Physical Laboratory, with the addition of some aspects of the work of the Building Research Station, the Chemical Research Laboratory, the Radio Research Organisation, the Fuel Research Station and the Mechanical Engineering Laboratory. In view of this, any account of its annual report is necessarily highly selective and incomplete. The name of the Bureau is but little guide to the nature of its activities, but it does partly justify its description as a Bureau of Standards by calibrating and testing a wide range of material and instruments for the Federal Government and industry. The report states that its "testing activities are mainly directed towards ensuring that materials purchased by the Government conform to specifications." During the year, 300,000 tests and calibrations were performed for Government agencies and the public.

In the present state of the world, it is no surprise to read that "the bulk of the Bureau's effort has been directed to research and development for defence." Major programmes have been concerned with electronic ordnance (including proximity fuzes), guided missiles and atomic energy. The report is divided into a series of sections, each dealing with a particular branch of work, such as electricity, heat and power, metallurgy, etc., and various matters referred to under one or other of the headings clearly have relation to defence research. This applies, for instance, to an investigation on jet-engine fuels. Such fuels "should burn fast, leaving a minimum of smoke, and should have a high heat of combustion in relation to their weight." The matter is being studied by synthesising a number of hydrocarbons having different structures from which it is hoped to determine which type of compound satisfies the requirements of a jet engine to the greatest extent.

Specific information is given about a thermocouple designed for flight service in jet engines in which the gas temperature is above the range of converted thermocouples. The elements are made of irridium and an irridium-rhodium alloy, and the instrument may be used at temperatures up to 3,700 deg. F. The insulating material is thoria and the uncooled supporting tube is molybdenum, protected from oxidation by a coating of molybdenum disilicide. The thermoelectric power is rather low, but is large enough to be measured by modern potentiometer indicators or recorders. The silicide-coated tubes have a relatively short life, but it is in excess of the duration of the flight applications for which the unit has been designed.

These examples constitute but a small part of the investigational work in the engineering field. Among other projects referred to is a laboratory which has been established to develop pneumatic equipment to operate at higher pressures than have been used. The immediate object in view is saving in weight and space in aircraft pneumatic systems, the higher pressure also resulting in greater actuation speeds. It is thought that storage pressures of 3,000 lb. per square inch will be found to be justified. An example in a different field is work on the fatigue strength of structures, particularly in reference to aircraft. In the heavy engineering sphere, mention may be made of a 3,000,000-lb. compression dynamometer developed for use in calibrating large testing machines.

Mention of these various examples must not be taken to indicate that the Bureau is primarily concerned with engineering matters. Probably its main sphere is physics, with considerable work in the field of chemistry, both organic and inorganic; this includes the study of blood plasma and co-operation in the building up of a national stockpile. Radio occupies a prominent position in the wide range of physical research. The work is divided into four branches, one concerned with ionospheric research on the nature of the upper atmosphere; one operating an information service supplying Government and commercial users with ionospheric data; the third studying the practical problems of radio communication; and the fourth consisting of a measurements standards laboratory mainly concerned with the development and maintenance of primary standards of electrical quantities at all radio frequencies. Finally, a research which may possibly lead to results of great practical importance is the development of refractory ceramic materials with favourable nuclear properties.

NOTES.

THE "COMET" AIR LINER.

THE total loss of a British Overseas Airways Corporation Comet air liner, with all on board, shortly after taking off from Calcutta, on May 2, the first anniversary of the inauguration of the first jet-propelled passenger-carrying air service, has distressed the whole nation. The cause of the accident cannot yet be stated, but it is known that unusually severe atmospheric storms were prevailing in the area. It is important that the disaster should not be allowed to mask unduly the fine record of service and freedom from major "teething" troubles achieved by the B.O.A.C. Comet fleet during the first year of commercial operation. The inaugural flight, on May 2, 1952, was on the London-Johannesburg route. Since then, three more Comet routes have been opened—London-Ceylon, London-Singapore, and London-Tokyo. During the year, Comet air liners have flown 104,600,000 revenue passenger miles, have carried 27,700 revenue passengers, and have made some 250 return flights. The Chairman of the Corporation, Sir Miles Thomas, commenting on the anniversary, said that the Comets had made sufficient profit in the year to cover interest on capital. Operating on the present routes, with a 75 per cent. load factor, the Comet showed a profit. In 1954, the Corporation expect to fly the Series 2 Comet on the London-South America route, and possibly between London and Sydney. A Series 2 Comet will also be used for upper-air exploration over the North Atlantic in preparation for regular operation with Series 3 Comets some three years later.

PROFESSIONAL ENGINEERS' APPOINTMENT BUREAU.

Although during the first half of 1952 the number of vacancies notified to, registrations received and successful nominations made by the Professional Engineers' Appointment Bureau, 9, Victoria-street, London, S.W.1, were above the average of those of previous years, the position during the second six months was less satisfactory. The result was that the annual total of notifications of vacancies was 969, or 10 per cent. less than the normal average. Of these notifications, 253 were for civil, 482 for mechanical and 234 for electrical engineers. The total number of nominations made was 8,751, of which 2,210 were for civil engineers, 4,731 for mechanical engineers and 1,810 for electrical engineers. Enrolments at the end of the year were 1,975, compared with 1,679 in 1951, of whom civil engineers accounted for 476, mechanical engineers for 1,025 and electrical engineers for 474. Since the Bureau began operations, appointments had been found for over 1,250 engineers, the total during 1952 being 171. There was a steady demand for men for overseas appointments, those in Canada and the United States being particularly attractive owing to the good prospects and high salaries. A considerable proportion of these overseas posts were, however, in Africa, India, Pakistan and the Middle and Far East. In spite of the efforts made, there was less success than in 1951 in placing men of over 50 years of age. Another difficulty was finance. In the past, the Bureau had relied for a large proportion of its revenue on voluntary donations from industry. The continuance of this policy was, however, considered to be undesirable; and it had therefore been decided that it would be preferable to charge employers an engagement fee when an appointment had been finally made as the result of the Bureau's nomination. This fee was to be based on 1½ per cent. of the gross initial annual salary paid to an engineer engaged in this way.

THE INSTITUTION OF CIVIL ENGINEERS ANNUAL DINNER.

The annual dinner of the Institution of Civil Engineers, with Mr. H. F. Cronin, C.B.E., M.C., President of the Institution, in the chair, was held at the Dorchester Hotel, Park Lane, on the evening of April 30, last. The toast of the Institution was proposed by the Rt. Hon. Baron Radcliffe of Werneth, P.C., G.B.E., who, in the course of his remarks, said that while he respected the civil engineer, he himself had drifted into law and, in the course of his career had had much to do with technical witnesses. He related how the Revenue Department, in 1890, attempted to assess the Institution with Corporation Tax, which, by present-day standards, amounted to practically nothing, but which moved the Victorians to take their case to the House of Lords, and the question whether the Institution existed for the amusement or the education of its members was finally settled by great lawyers who saw the obvious with great clarity. He concluded by referring to Tredgold's definition, which was the motto of the Institution, "The art of directing the great sources of power in Nature for the use and convenience of Man," and said roads, bridges and canals were marks of the civilising influence of the civil engineer, and were enduring monuments in Africa, India, the Far East, the great Dominions, and in other remote parts of the world. Mr. Cronin, in replying, stressed the necessity for more work and said the railways, roads, bridges, docks and canals were the work of former generations of civil engineers. He pointed to the amazing recovery of the French State Railways since the war, and the still more amazing recovery of the Dutch, through persistent hard work. In Western Germany, they were working even harder. He added that if this country was to pay for the food it needed, we must work much harder. There were over 19,000 members of the Institution, who could surely set an example by making a point of coming early to work and leaving late, instead of coming late and leaving early. Mr. A. S. Quartermain, C.B.E., M.C., Past-President and Member of Council, proposed the toast of the guests, and the Rt. Hon. Viscount Runciman of Doxford, O.B.E., A.F.C., President of the Institution of Naval Architects, responded.

CONFERENCE ON BORON IN STEEL.

On Wednesday, April 29, the day preceding the annual general meeting of the Iron and Steel Institute, a special meeting, arranged at the suggestion of the Ministry of Supply, acting in conjunction with the Organisation for European Economic Co-operation, to discuss "Boron in Steel," was held at the Institute's headquarters in London. In the unavoidable absence of the President, Captain H. Leighton Davies, C.B.E., the chair was occupied by the honorary treasurer, Mr. W. Barr. At the morning session a paper on the "Manufacture of Boron Steels" was presented in full by Mr. L. J. Rohl, of the United States Steel Company. He stated that boron was being used to replace nickel and molybdenum and, to some extent, chromium, in constructional alloy steels, for producing tractor and Diesel-engine components, hand tools, and other articles. The permissible range of boron to impart satisfactory "hardenability" and hot-working characteristics to steels lay between 0·0005 and 0·007 per cent., and, by its use, savings of 27·6 lb. per ton of nickel and 2·6 lb. per ton of molybdenum were being obtained. The production of boron steels in the United States had risen from about 25,000 ingot tons in 1950 to 350,000 tons in 1951 and 700,000 tons in 1952. At the afternoon session, Mr. H. B. Knowlton, of the International Harvester Company, spoke on the "Use of Boron Steels." He said that a great deal of progress was being made in the conservation of nickel, and molybdenum, in the manufacture of steel components requiring high mechanical properties. His company had succeeded in replacing about 70 per cent. of its annual tonnage of alloy steels, containing nickel and molybdenum, with a series of chromium-boron steels without impairing in any way the performance of their products, which included motor vehicles and tractors of all types, some operating under very severe conditions. In a third paper, entitled "Effect of Boron on the Mechanical Properties of Low-Alloy Steels," presented by Mr. R. Wilcock, works metallurgist of Samuel Fox and Company, Limited, an account was given of experiments conducted on three low-alloy carbon-manganese steels of the En.15 type, containing 0·35 per cent. of carbon, 1·45 per cent. of manganese, and from nil to 0·20 per cent. of molybdenum; one En.16 steel, of similar composition but containing 0·28 per cent. of molybdenum, and one modified American NE 8640 steel of the following percentage composition: carbon 0·40, manganese 0·90, nickel 0·55, chromium 0·40, and molybdenum 0·12. In each of the five steels studied, two ingots were cast, the first being boron free and the second boron-treated. The author stated that tensile and impact tests in the hardened and tempered conditions had been carried out in a range of sizes up to 4 in. square, and the hardenability investigated by Jominy end-quench tests. It was concluded that the possibility of conserving alloying metals was confined to the intermediate size group. On the basis of specifications En. 15, 16 and 17, the molybdenum saved by the use of boron varied from nil up to about 0·20 per cent., depending on the size. In small sizes, tempered at 400 deg. C., or below, boron improved the impact values and, to a less extent, the ductility.

THE INSTITUTION OF BRITISH AGRICULTURAL ENGINEERS.

The Institution of British Agricultural Engineers held their annual luncheon at the Horse Shoe Hotel, Tottenham Court-road, London, W.1, on Wednesday, April 29 last. After welcoming the guests, the President, Mr. D. P. Ransome, called up the guest of honour, Professor Sir James Scott Watson, C.B.E., M.C., LL.D., Director-General of the National Agricultural Advisory Service, to propose the toast of the Institution. Sir James said that he had been absorbed in agricultural progress for more than half a century. He spoke of the history and advances that had occurred in this particular field of engineering from the days when the plough and yoke were made in the workshops of village blacksmiths, and mentioned that Reading University had recently set up a museum of rural life. He suggested that the Institution might consider celebrating the centenary in four years time, of the winning, by John Fowler, of the Royal Agricultural Society's 500*l.* prize for a successful ploughing tackle in 1858, this being the first time that the application of mechanical power to the cultivation of soil had been recognised. One of the most urgent mechanical needs of the farmer to-day, he thought, was a good potato-harvester. The President, in his reply, said we were inclined to forget that 50 years ago we were the biggest exporters of agricultural machinery in the world, and to-day we hold second place. We lost our markets to the United States at the beginning of the century and the middle 'twenties. To-day we exported 60*l.* million worth a year. The Institution, he said, was trying to raise the standard of the machinery produced in this country, and was endeavouring to guide young people in the direction through which this might be achieved. The introduction of the National Diploma some two years ago was a step in the right direction. On the subject of taxation, he felt most strongly that the membership fees to learned institutions should be exempted from a member's income tax, without the necessity for a statement from his employer saying that membership was a condition of his employment, and he asked those Members of Parliament present if they would carry these views back to the House with them. He spoke of the Institution's need of more funds, and expressed thanks to the Society of Motor Manufacturers and Traders, and the Agricultural Engineers' Association, for donations they had made.

OPERATIONS OF THE AIRWAYS CORPORATIONS.

The Ministry of Civil Aviation have recently issued the operating and traffic statistics of the United Kingdom airways corporations and their associated companies for 1952. During the year more than 1½ million passengers were carried on scheduled services—267,000 by British Overseas Airways Corporation (B.O.A.C.), 1,338,000 by British European Airways (B.E.A.), and 95,000 by the associated companies, these figures representing an increase over the corresponding figures for the previous year of 11·7 per cent., 19·3 per cent. and 74·3 per cent., respectively. The aircraft mileages flown during 1952 by B.O.A.C. were 31·6 million (an increase of 6·6 per cent.); by B.E.A., 23·5

million (an increase of 10 per cent.); and by the associates, 2·5 million (an increase of 74 per cent.). The total freight traffic dropped slightly to 30 million short ton-miles, whereas mail traffic rose by 7 per cent. to over 18½ million. In general, the improvement in traffic was less marked than in the previous year, as a result of various factors, such as the fuel strike in the United States, political disturbances in the Middle East, the reduced travel currency allowance, import restrictions in Australia, and South Africa, etc. B.O.A.C. flew 847 million passenger miles, of which roughly two-thirds were on Eastern routes. The Western routes, however, showed a bigger increase—13 per cent.—over the previous year, largely as a result of the introduction of tourist fares. B.E.A. flew a total of 357 million passenger miles, an increase of 16·6 per cent. over the previous year, of which 251 million passenger miles (12 per cent.) were on international routes, and 106 million passenger miles (28 per cent.) on domestic routes. The associated companies' passenger traffic increased by 132·2 per cent. to over 25 million passenger miles. B.O.A.C.'s available seat miles increased by 10·7 per cent. to 1,320 million, B.E.A.'s by 19·7 per cent. to 552 million, and the associated companies' by 112·9 per cent. to 37 million. The passenger load factors, i.e., the ratio of the number of passengers carried to the seats available, were 64·2 per cent. (B.O.A.C.), 64·6 per cent. (B.E.A.), and 67·7 per cent. (associates). The average annual utilisation achieved by B.O.A.C. was 2,003 revenue hours per annum per aircraft, compared with 2,041 for the previous year, and by B.E.A., 1,654 hours compared with 1,550 hours the previous year.

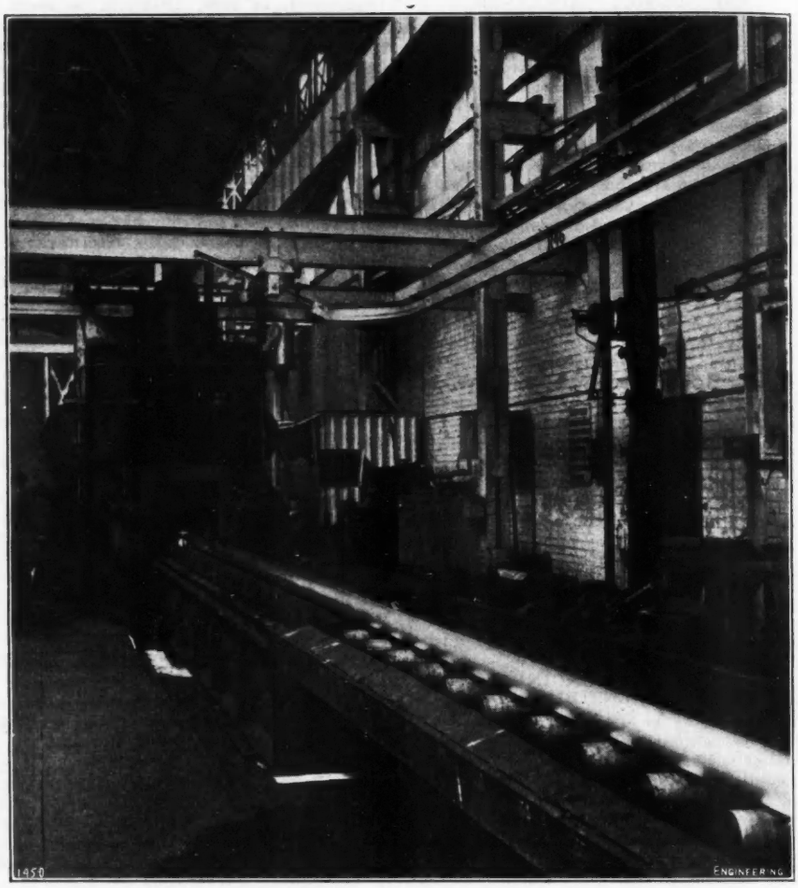
132-KV SUBMARINE IMPREGNATED PRESSURE CABLE.

The first three-core 132-kV submarine impregnated pressure cables are now being laid by British Insulated Callender's Cables, Limited, Norfolk-street, London, W.C.2, between the Rozelle and Homebush sub-stations on the outskirts of Sydney, Australia, a distance of 5 miles. The work includes the crossing of a tidal arm of the Parramatta River, for which purpose two 404-yd. lengths of submarine cable are being used. The minimum thickness of the sheath of these cables, which encloses the 0·3-sq. in. screened circular copper conductors, has been increased from 0·125 in. to 0·145 in., compared with the land cables, and has been reinforced with tin-bronze tapes and strips, instead of with steel, besides being armoured with a single layer of galvanised-steel wires 0·16 in. in diameter to guard against corrosion. This armouring is applied over anti-corrosive protection, consisting of cotton, rubber and hessian tapes and is itself served with two layers of bitumen-impregnated hessian tapes. The overall diameter of the submarine cables is 5·29 in. compared with 4·59 in. for the unarmoured land cables and their weight is about 90 lb. per yard, as against 62 lb. A gas channel pipe with an internal diameter of 0·25 in. and an external diameter of 0·375 in. is laid up in one of the filler spaces between the cores and is used to carry nitrogen gas at a pressure of 200 lb. per square inch. The two circuits are each capable of transmitting a continuous load of 85 MVA, or if both circuits are loaded simultaneously they can each carry 77·5 MVA. They could actually be loaded to a higher figure, but their ratings are controlled by the fact that the shore ends and the cable runs generally are laid directly in the ground and that the quoted ratings apply with a temperature of 20 deg. C.

THE FIRST TEN YEARS OF THE NUFFIELD FOUNDATION.

A "Review of the First Ten Years 1943-53" has been issued recently by the Nuffield Foundation, Nuffield Lodge, Regent's Park, London, N.W.1. The Foundation was established in April, 1943, by Lord Nuffield for the advancement of health and social well-being, the care and comfort of the aged poor, the advancement of education, and other charitable purposes. Over the ten years the Foundation's total income amounted to 5,245,675*l.* and the grants awarded to 4,208,586*l.*, of which 786,000*l.* had been for medical work, 347,000*l.* for, biological research, 560,000*l.* for research in physics, 463,000*l.* for social-science projects, 32,000*l.* for agriculture and 463,000*l.* to miscellaneous grants, 925,000*l.* to the care of old people, and 831,000*l.* to fellowships and scholarships (about half for residents in the United Kingdom, and half for other Commonwealth citizens. Grants for projects connected with the Commonwealth outside the United Kingdome amounted to 216,000*l.* Among these latter projects may be mentioned the endowment of a Nuffield research chair of mechanical engineers at the New University of Technology in New South Wales, Australia. Medical grants, totalling 150,000*l.* had been made to three universities in industrial areas—Durham, Glasgow and Manchester—for establishing departments of industrial health. A grant of 15,000*l.* had been contributed to a "working model" of an industrial health service on the Slough trading estate. One of the first concerns of the Foundation was to help re-establish university research in fundamental physics at the critical time when scientists were being released from their war-time posts. Grants totalling 105,000*l.* were made to the physics departments of Birmingham, Manchester and Glasgow Universities for re-creating and re-staffing nuclear research. Grants for research fellowships in low-temperature and nuclear physics had been made to Oxford University, which would total 84,000*l.* over a period of 13 years. Other physical-research projects in which the Foundation had assisted include crystallographic research at Birkbeck College, and the development of the radio-telescope at Manchester, the reflecting microscope at Bristol and a new electronic computer at Cambridge. The Foundation consider that more fundamental research in metallurgy should be carried out at universities, and accordingly a Nuffield research group in extraction metallurgy was started at the Royal School of Mines. Two new projects at Cambridge in geology and mineralogy had received Nuffield awards.

LARGE ALUMINIUM TUBE FOR CABLE SHEATHING.



LARGE ALUMINIUM TUBE FOR CABLE SHEATHING.

THE accompanying illustration shows an 8,000-ton press which was constructed by Messrs. Fielding and Platt, Limited, Gloucester, and has been in operation since 1942 in the Rogerstone works of the Northern Aluminium Company, Limited, Banbury, for the production of large aluminium-alloy extrusions—most of them aircraft wing-spar sections. It has, however, been employed more recently for extruding large aluminium tubes, 20 of which will be used to sheath a power transmission cable in Canada. Each tube, one of which can also be seen in the illustration, is 400 ft. long, and has an external diameter of 4¼ in., the wall thickness being 0·17 in. As each length emerges from the press it is coiled on a drum 12 ft. in diameter and 6 ft. wide, with a barrel 10 ft. in diameter, these dimensions being necessary to allow coiling to be effected without damage, as well as permitting the tube to be successfully restraightened when it is eventually uncoiled.

These lengths of tubing are to be employed for sheathing a paper-insulated hollow segmental aluminium conductor which will be used to transmit power at 300 kV from a power-house near Kemano, British Columbia, to the smelter which the Aluminium Company of Canada are building at Kitimat. The diameter of the conductor is 3½ in., while that of the finished cable, after the sheath has been pressed on to the core, is about 3·85 in.

75-WATT REFLECTOR SPOT LIGHT.—A 75-watt reflector spot light now being manufactured by the British Thomson-Houston Co., Ltd., Crown House, Aldwych, London, W.C.2, is designed to fit an ordinary lamp holder. It consists of an internal parabolic-type reflector and satin-frosted crown and emits a beam of controlled light, which should render it useful for close work in machine shops, garages, shop windows, etc.

THE IRON AND STEEL INSTITUTE.

THE 84th annual general meeting of the Iron and Steel Institute was held in London on Thursday, and Friday, April 30 and May 1. At the outset of the proceedings, Captain H. Leighton Davies, the retiring President, occupied the chair. In the course of his preliminary remarks, Captain Davies announced that, as a result of meetings and discussions with representatives of the American Iron and Steel Institute, the American Institute of Mining and Metallurgical Engineers, and the American Society for Metals, there were prospects that a joint American metallurgical meeting would be held in Europe in 1955. Continuing his announcements, the President said that, so far, it had not been the custom of the Institute to appoint a President-elect until about three months before he was due to take over office, but the Council had decided to do this well in advance in the future. The next President to follow Mr. James Mitchell, C.B.E., who would hold office in 1953-54, would be the Hon. R. G. Lyttelton. Captain Davies's last announcement was that the lease of the Institute's offices at 4, Grosvenor-Gardens, London, S.W.1, was due to expire in 1955, but, as a result of a generous response to an appeal for financial assistance made to iron and steel firms in this country, a new lease to last for a further 60 years had been negotiated.

REPORT OF COUNCIL.

The President then proposed the adoption of the report of Council for 1952. This showed that the total membership of the Institute, on December 31, 1952, was 4,801, compared with 4,776 on December 31, 1951. With the ending of the state of war with Japan on April 28, 1952, the Council had decided that persons of Japanese nationality were again eligible for membership. The deaths of 43 members were reported with regret. Among them were Mr. W. J. Brooke, Mr. W. C. Devereux, Sir Andrew Duncan, P.C., G.B.E., Sir William T. Griffiths, Mr. H. S. Levick, Mr. Aloyse Meyer (Bessemer Medallist in 1937), Dr. G. Vanzetti and Dr. G. B. Waterhouse. The Institute had continued to collaborate as closely with the British Iron and Steel Research Association as in previous years. The library, information and abstracting services were available to the staff and member firms of the Association, and the Institute's *Journal* continued to be the principal medium for the publication of the research results and reports of the Association. The friendly relations existing between the Institute and other metallurgical and scientific institutions in this country and overseas had continued, and a number of joint meetings, in England and Wales and Scotland, had been held during 1952. The Joint Committee for National Certificates in Metallurgy had approved five new schemes for the Certificates during 1952, and other schemes had been revised. Moreover, schemes were being organised in districts not yet covered, with a view to the starting up of courses as soon as possible.

REPORT OF HONORARY TREASURER.

The statement of accounts, presented by Mr. W. Barr, who said that he had taken over the position of honorary treasurer from the President-elect, Mr. James Mitchell, C.B.E., on January 1, 1953, showed that the income for the year ended December 31, 1952, was 69,540*l*. The normal expenditure was 66,213*l*., and the total expenditure after including non-recurring items was 67,111*l*. The excess of income over expenditure transferred to the balance sheet was 2,429*l*. In seconding the adoption of the statement of accounts, proposed by the President, Mr. Barr asked the members to do their utmost to add to their numbers as this would be of great help to the finances of the Institute.

PRESENTATION OF MEDALS AND PRIZES.

Captain Leighton Davies then presented the medals and awards made during the year. The first, the Bessemer Medal for 1953, was handed to Mr. R. Mather, chairman and managing director of the Skinningrove Iron Company, Limited, and a past-president of the Institute. The President stated that Mr. Mather had been awarded the medal for his distinguished services to the Institute and to the industry. In returning thanks for the honour conferred upon him, Mr. Mather recalled that four other old students of the late Professor J. O. Arnold, F.R.S., of Sheffield University, beside himself, had been awarded the medal, namely, Mr. W. J. Dawson, C.B.E., the late Dr. W. H. Hatfield, F.R.S., the late Dr. T. Swinden, and Dr. H. H. Burton, C.B.E.

The Sir Robert Hadfield Medal for 1953 was presented to Mr. W. E. Bardgett, research manager of the central research laboratories of the United Steel Companies, Limited, in recognition of his contribution to the development of alloy steels, with particular reference to materials for service at elevated temperatures. An Andrew Carnegie Silver Medal for 1952 was handed to Dr. E. T. Turkdogan, now with the British Iron and Steel Research Association, for his researches on slag-metal reactions reported in papers written in collaboration with Dr. W. R. Maddocks, namely, "The Effect of Sodium Oxide Additions to Steel-making Slags, Parts I and II," and "Phase Equilibrium Investigation of the Sodium Oxide-Phosphorus Pentoxide-Silica Ternary System." The Ablett Prize for 1952, of a value of 100*l*., was presented jointly, involving a sum of 50*l*. to each, to Dr. S. A. Burke and Mr. G. A. Sparham, of the British Coal Utilisation Research Association, for their paper on "Automatic Control of Coal Feed in Steelworks Gas Producers."

CHANGES IN COUNCIL AND ANNOUNCEMENTS OF MEETINGS.

On being called upon, the secretary announced that the following had been made honorary members of Council during their tenure of office: Professor F. C. Thompson, President of the Institute of Metals, in succession to Dr. C. J. Smithells; Mr. W. B. Wragge, President of the Manchester Metallurgical Society, in place of Mr. H. Allison; Mr. H. Hicks, President of the Sheffield Metallurgical Association, in place of Mr. E. W. Colbeck; Mr. A. W. Shore, President of the Staffordshire Iron and Steel Institute, in place of Mr. W. Regan, and Mr. A. McKendrick, President of the West of Scotland Iron and Steel Institute, in place of Professor R. Hay. Moreover, in accordance with by-law 10, the three vice-presidents, namely, Mr. G. Steel, the Hon. R. G. Lyttelton and Mr. I. F. L. Elliot, and five members of Council, namely, Mr. D. F. Campbell, Mr. G. H. Johnson, Mr. D. A. Oliver, Dr. C. Sykes, F.R.S., and Mr. W. Barr, who, as announced at the autumn meeting of 1952, were due to retire in rotation at the present annual meeting, were declared to be re-elected, no other nominations having been received.

The secretary then announced that a special meeting would be held in Holland, at the invitation of Mr. A. H. Ingen Housz, of the Royal Dutch Iron and Steel Works, from September 30 until October 6, 1953. The autumn general meeting of the Institute would be held in London on November 25 and 26, 1953. Next year, 1954, the annual general meeting would be held in London on May 26 and 27 and an invitation from Jernkontoret to hold a meeting in Sweden had been accepted. The opening date was Saturday, June 5, 1954, and the meeting would last about a fortnight.

INDUCTION OF NEW PRESIDENT.

At this stage of the proceedings, Captain H. Leighton Davies inducted the President-elect, Mr. James Mitchell, C.B.E., into the chair and, in doing so, recalled Mr. Mitchell's services to the Institute as honorary treasurer and his keen interest in the production side of the iron and steel industry. After a vote of thanks to the retiring President had been passed with acclamation, Mr. Mitchell delivered his presidential address which, he stated, dealt in broad general terms with the subject, "From Iron Ore to Steel Ingot." He said that in 100 years of steel metallurgy there had been no revolutionary changes; nevertheless the developments which had taken place had been remarkable. Many of the improvements in equipment had been due to the work of the mechanical and electrical engineer. Thus, hand charging of blast furnaces had been replaced by mechanical apparatus and old-type blowing engines had given way to turbo-blowers. Even the latter would probably be replaced, at some time in the future, by gas turbines. Furthermore the hot-metal ladles and the mixer, to a large extent, had done away with the heavy manual work at the blast-furnace pig beds.

The total heat energy required to reduce iron oxide by carbon monoxide and to produce one ton of steel was, theoretically, about 8½ million B.Th.U. In practice, however, some 20 million B.Th.U. were required; about 15 million in the blast furnace and from 3 to 5 million in the steel furnace. In smelting ore, the chief problem was not the melting of the iron but the removal of impurities. The blast furnace, therefore, was really an eliminator of impurities and a "concentrator" of raw material. The blast furnace, however, did not yield a pure product and steel manufacture was largely a refining process. The capital cost of a modern blast-furnace was very high and among the developments put forward in recent years to increase efficiency were the introduction of high top pressure and the building of low-shaft furnaces. High top pressure seemed to be a logical development which gave encouraging results. Low-shaft furnaces, on the other hand, presented many problems needing a solution. Direct processes for smelting iron had often been discussed but there was no future in these unless pure materials were available; in other words, the ore used had to be treated so as to produce pure iron oxide. It was symptomatic that the only country to have made any headway with direct processes was Sweden, where the native ores were pure.

The thermal efficiency of a Bessemer converter was high, usually about 54 per cent. This was higher than the values for the open-hearth or electric furnace. It was not easy, however, to determine the efficiency of an open-hearth furnace, even when the charge consisted of 100 per cent. pig iron. Whereas, in the Bessemer process, heat was generated within the metal, in the open-hearth process heat had to be added. The thermal efficiency of the open-hearth furnace, however, normally lay between 15 and 20 per cent. It was often questioned whether Bessemer steels were as good as similar steels made by other methods. In answer to this, it should be emphasised that the modifications introduced, in the last few years, into basic-Bessemer steel manufacturing technique had made this material suitable for at least 90 per cent. of industrial steel applications. In a final reference to finishing operations in the steel melting shop, Mr. Mitchell thought that further research was needed to produce deoxidisers which would not tend to leave solid oxides in the steel.

The remainder of the morning of Thursday, April 30, and the whole of Friday, May 1, were devoted to the presentation and discussion of papers.

ANNUAL DINNER.

The toast of the "Iron and Steel Institute and Industries" at the annual dinner of the Institute, attended by well over 1,000 members and guests and held at Grosvenor House, Park-lane, on the evening of April 30, was proposed by Lieut.-General Sir Ian Jacob, K.B.E., C.B., director-general of the British Broadcasting Corporation. In reply, the President, Mr. James Mitchell, C.B.E., stated that the Institute believed that the individual member was more important than the corporate body and the aim was to develop the individuality of each member. Many subjects of wide variety were covered in the proceedings of the Institute, as had been exemplified by the papers presented at the present annual general meeting. When proposing the toast of "The Guests," Sir Andrew McCance, D.L., D.Sc., F.R.S. LL.D., stated that, in this country, there had always been a very close association between the Services and the industry. In the course of his reply to this toast, Admiral Sir Rhoderick McGrigor, G.C.B., D.S.O., the First Sea Lord, said that, during the late war, the Navy had ordered 6½ million tons of steel. One problem which faced the Admiralty was to maintain ships, that had to be held in reserve, in good condition. In meeting this successfully a great deal of help had been furnished by scientists and metallurgists.

(To be continued.)

FLARE STACKS FOR BRITISH OIL REFINERIES.

AN unusual design has been used for five of the flare stacks erected at the three major oil refineries in the United Kingdom belonging to the Anglo-Iranian Oil Company, Limited. One of the two stacks erected at Llandarcy, in Wales, is shown in Fig. 1, on page 592. The stacks, 2 ft. in diameter and supported by guyed steel-lattice masts 250 ft. high, are used to burn off the waste gases from the catalytic-cracking plant and other process units. The gas is ignited at the top of the stack by a constantly-burning pilot flare which can be relit by an electrically-operated flame-propagation unit in the case of failure. The masts, two of which are at Llandarcy in Wales, one at Grangemouth in Scotland, and two at the Isle of Grain in the Thames Estuary, have been designed, supplied and erected by British Insulated Callender's Construction Company, Limited, 21, Bloomsbury-street, London, W.C.1. The same company also erected the stacks, and installed the electrical equipment.

The lattice-type of supporting mast—the foot of one of the masts is shown in Fig. 2—is believed to be the first of its kind to be used in the oil industry and was chosen for two reasons. Firstly, on economic grounds, for it is only two-thirds the steel weight of a comparable self-supporting structure, and, secondly, because it would have been extremely difficult to provide reliable foundations for an unstayed tower on the marshy sites involved. The masts were designed on principles similar to those used for the 750-ft. television aerial masts erected at each of the four post-war television stations of the British Broadcasting Corporation. The height of the stack was governed by the tremendous heat associated with the burning, which eliminates the possibility of any work within a range of approximately 350 ft., so that the higher the flare head, the greater the area of ground in the proximity of the base of the mast which can be used for refinery buildings.

The cross-sectional area of the stack is based on a maximum rate of flow of waste gas of 1½ million cubic feet an hour, and the maximum temperature of the flame is estimated to be 1,000 deg. F. During maximum discharge, the flame might attain a length of 50 ft. Despite the quantity of gas involved, the function of the stacks is only that of a safety-valve for burning surplus waste; waste-heat recovery is practised to the maximum effect.

SUPPORTING MAST.

The 235-ft. mast is triangular in cross-section, with 6-ft. wide faces, the corner members being two standard angles battened together. The total weight of the mast is 21 tons and the bracing system is double-Warren panels, 7 ft. long, with the exception of the two adjacent to the stay-attachment point, which are only 5 ft. long. Any part of the mast can be reached via an external caged ladder, shown in Fig. 2, with rest platforms provided at approximately 60-ft. intervals. At the head of the mast there is a working platform.

Three stays are attached to the corner members of the mast at the 174-ft. level, the ground ends being secured to concrete anchorages through a length-adjusting device, comprising a crosshead which can slide along two parallel screwed rods. These devices are necessary to ensure that the calculated still-air tensions are imposed on the ropes during erection and, also, to take up any inelastic stretch which may develop due to bedding down of strand wires after they have been in service. The mean elevation of the stays is 53 deg. with the horizontal. At the mast base a rocker bearing is formed between two steel plates, the lower of which is slightly convex. A 2-in. diameter steel ball, recessed equally and centrally into these plates, takes the whole weight of the mast, at the same time affording free angular movement to the mast.

The masts have been designed to withstand a wind velocity of 75 miles per hour; in such a wind, it is expected that the mast head will move approximately 2 ft. 6 in. from the perpendicular. The masts were stayed only at the 174-ft. level because, although it would have been more economical to use two sets of supporting guys, the poor ground conditions at both Grangemouth and the Isle of Grain were likely to permit unequal settlement of the stay anchorages which, with two sets, would set up damaging strains.

FLARE STACKS AT BRITISH OIL REFINERIES.

BRITISH INSULATED CALLENDER'S CONSTRUCTION CO., LTD., LONDON.

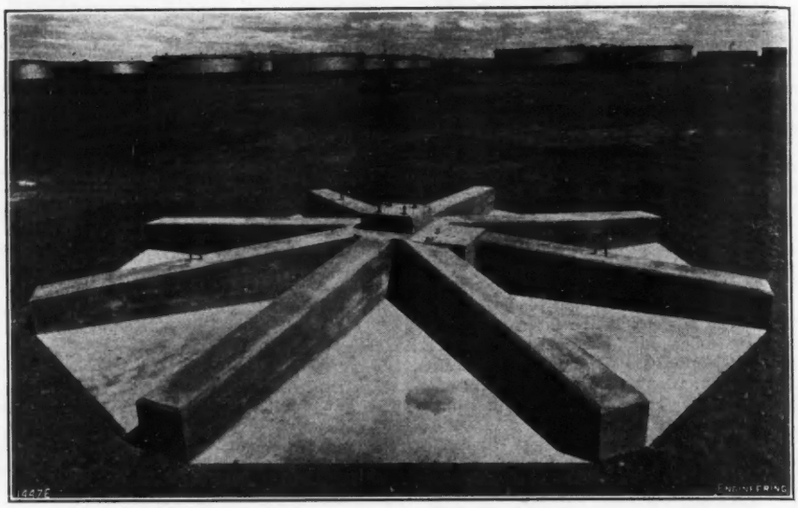


FIG. 5. FOUNDATION PAD AT GRANGEMOUTH.

FOUNDATIONS.

The varying ground conditions at the three sites required three different types of foundations. At Llandarcy, the ground is firm and, although there is a general slope of 30 deg., conventional foundations were possible for the masts and stay anchorages. One problem was encountered at Llandarcy, however, because whatever the orientation of the mast the anchorage of one of the stays would have been placed in a 30-ft. depth of newly-made ground. This was obviated by replacing the one stay with two others which were each attached to a face of the mast; the particular mast concerned is that shown in Fig. 1. The two stays have a horizontally included angle of 120 deg. and they are secured to the mast through special frames that allow their lines of action to pass through the centre of area of the mast section.

At Grangemouth, even piles driven to a depth of 80 ft. had failed to give reasonable bearing values, so that all the refinery buildings are built on reinforced-concrete rafts. The mast foundation, shown in Fig. 5, above, is an octagonal raft, 1 ft. deep and 30 ft. across opposite faces, with eight radial stiffening beams, 18 in. wide, projecting 2 ft. 6 in. above the raft at the centre, but tapering to a depth of 18 in. at the end. The base dimensions of the stay anchorages were enlarged to compensate for the low ground resistance available. As piles gave reasonable bearing values on the Isle of Grain site, the mast bases each consist of four piles.

FLARE STACK.

The flare stack itself is a 2-ft. diameter mild-steel pipe, with ⅜-in. thick walls, made up of 25-ft. sections welded together after erection. The total weight is approximately 11½ tons. During the erection of the mast, the first section of the flare stack—shown in Fig. 2—which includes an entry for the horizontal feed pipe from the process units, was placed in position and its weight taken through three adjustable distance pieces, shown in Fig. 3, on page 592, inserted under a collar specially welded to this section of pipe and resting on the supporting frame of the mast. Before entering the vertical stack in the mast, the horizontal feed enters a knock-out drum, 8 ft. in diameter and 16 ft. long, which traps any liquid carried in suspension by the waste gases.

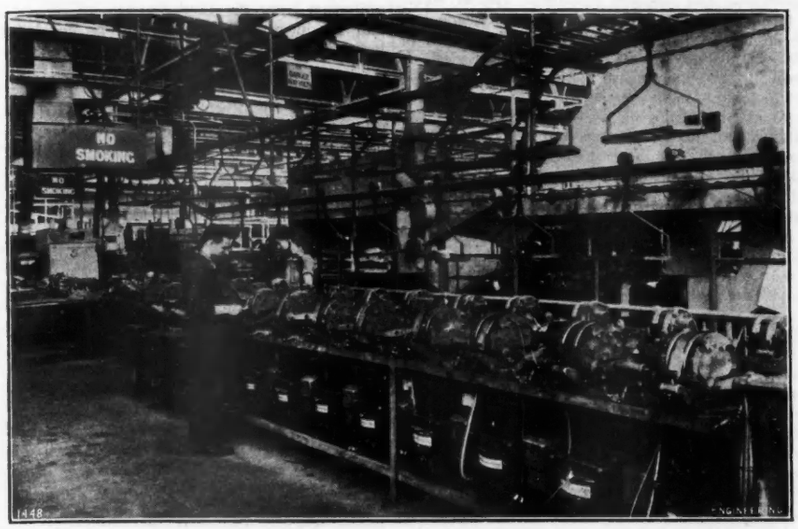
After the mast had been erected, the other sections of the flare stack were hauled to the top of the mast and then lowered through the structure. At one end of each section a 4-in. wide ring, 25 in. in diameter, was welded to form a short sleeve with an overlap of 2 in. The bottom edge of each section was lowered into the overlap of the ring at the top of the lower section and, when the complete stack had been installed, these were fillet welded.

The stack is located centrally within the mast by horizontal frames spaced 7 ft. apart, and contact is made between stack and frame by three 2-in. diameter rollers spaced equally round the circumference. The rollers were necessary as, after welding the sections of the pipe, the complete stack was raised 4 in., and the support point taken to the 205-ft. level. The lifting operation was carried out by jacks at the base of the mast. The weight of the stack was finally transferred to the top support point and carried on three adjustable distance pieces inserted between a collar on the pipe and the frame of the mast. These distance pieces were eventually welded into position, at the collar and at the frame, to make a rigid fixture. During the lifting operation the lower distance pieces were adjusted to follow the stack as it was lifted in case there was any failure on the part of the jacks. The reason for suspending the stack at the 205-ft. level is that this was thought to be the highest point below which the thermal expansion, due to the immense heat at the flare tip, would be negligible. Such expansion as does occur puts no strain on the mast, the stack expanding freely within the side support of the roller guides.

Flange-bolted to the top of the stack is a 2-ft. long section of stainless-steel lined pipe which contains the flame arrester, consisting of layers of stainless-steel mesh. Similarly fixed to the arrester is the final length of stainless-steel pipe, 11 ft. long, which opens out at the head to a bell mouth 5 ft. 8 in. across. This final section, the flare tip, shown in Fig. 4, is heavily coated internally with an insulating refractory material. These two top sections have been bolted rather than welded in case they have to be dismantled for maintenance or replacement. Subsequent to the completion of the two masts at Llandarcy, it was found necessary to inject steam into the flare tip of one of the stacks, through a 4-in. diameter pipe, to minimise the amount of smoke which was being emitted, as it might possibly cause a public nuisance.

The waste gases from the catalytic cracking unit and other process plant are fed into the stack and ignited by a constantly-burning pilot flame located in the mouth of the flare tip; the pilot flame is fed through a 1-in. diameter mild-steel gas pipe from the refinery's fuel-gas system, the top 11-ft. section of gas pipe being of stainless steel. In the

BONDING BRAKE LININGS TO SHOES.



event of the pilot flare being extinguished an electrically-operated stainless-steel flame propagation tube is installed to re-light it. The propagation tube is 11 ft. long and 3 in. in diameter, open at both ends, with the top adjacent to the pilot head. It is fed by a 1-in. diameter pipe from the fuel-gas system, the top 11 ft. of pipe also being stainless steel. The gas enters the propagation tube at a series of levels, and the gas-air mixture is ignited by two independent high-voltage sparking plugs fixed to the tube, protected by special-alloy shields and energised from step-up transformers. The operation is push-button controlled from the refinery control room, and the propagation tube remains alight only as long as the push-button is depressed, the same action energising the sparking plugs and working a solenoid-operated valve which starts the flow of gas to the propagation tube.

At the base of the mast is a two-way 660-volt flameproof junction box connected to a compound-filled T service box at the guy attachment point (174-ft. level). The service box is connected to the primary terminals of two 440/10,000-volt transformers, which are at the same level. Each sparking plug—of the normal aircraft type—is connected to one of the transformers by single-core metal-sheathed mineral-insulated cable, the two plugs thus being on separate circuits. The transformer end of each cable has the metal sheath connected to the other terminal of the secondaries, while the sparking-plug end has the sheath bonded to the flame propagation tube by copper strip connected to clamped copper sleeves. The cable of this high-tension circuit consists of a robust solid-drawn malleable-copper tube with the copper conductor embedded and firmly located within a highly-compressed magnesium-oxide powder. These materials are inorganic, non-inflammable and non-ageing, and give a cable capable of withstanding considerable mechanical abuse without disturbing the relative position of the conductor.

In case the extreme heat damages the cable, a straight-through junction box is installed mid-way on each run, between the transformer and sparking plug, in an endeavour to reduce the amount of cable which might have to be replaced. Special terminals had to be developed for the cable as ordinary cold-seal terminations would break down under the heat. These were made by stripping back the metal sheath and mineral dielectric and passing the bared conductor through a corundite insulator, to which was swaged a copper-plated steel sleeve brazed at one end to the metal sheath of the cable. The conductor was brazed to the inside of a terminal stud on the corundite insulator. The corundite insulator came to within approximately $\frac{1}{8}$ in. of the magnesium-oxide powder in the cable and the ensuring void was not filled.

PRODUCTION OF GIRLING BRAKES AND DAMPERS FOR MOTOR VEHICLES.

THE main production factory of Girling, Limited—Grange Works, Cwmbran, Monmouthshire—turn out approximately 40,000 single brakes and 16,000 dampers a week. Full advantage has been taken of this high rate of output to reap the benefits of mechanisation, both in methods of production and in mechanical handling, and development and testing of brakes and dampers are well provided for at the company's headquarters at Tyseley, Birmingham, 11. We recently visited the two works on the occasion of the firm's 21st anniversary of their connection with the motor industry.

Though the Tyseley Works, which have a covered area of 102,000 sq. ft. and employ about 700 workers, are the headquarters of the company, only a comparatively small part of the manufacturing is done there. The administrative, sales and engineering departments are at Tyseley, where all the research and development work is also carried out. Equipment is provided for testing prototype brakes and dampers under many different conditions, and it is possible to conduct tests under conditions far more arduous than would ever be met in service. Tests can be carried out to destruction or for varying lengths of time, as required. Heenan and Froude dynamometers are used for brake-testing, and a "silent room," completely sound-insulated from the rest of the factory, is provided for investigating damper noises. In this room sensitive microphones are used to pick up the sounds from the dampers, and the results are given either audibly, through a loud-speaker, or visually, as a trace on a cathode-ray oscilloscope. An electric tape recorder is provided, so that noises, with a spoken commentary to identify them, can be recorded for comparison purposes. A fully-equipped prototype and experimental workshop is located at Tyseley, and complete dampers or brakes can be made and tested before being passed for production. Facilities are also available for fitting brakes and dampers to vehicles for testing purposes, and during the visit a Jaguar Mark VII motor-car was seen fitted with the new Girling "Hydrastatic" disc brake, which is not yet in production. Tyseley also produces the well known "Tracta" universal joint, which is used on front-wheel-drive vehicles, and for this purpose there is a fully-equipped machine shop and a heat-treatment department with nitriding plant. There is also a service department which provides a full maintenance service for dampers and brakes on road vehicles.

The Grange Works at Cwmbran were built by the former Ministry of Aircraft Production during the war, and were taken over by Girling, Limited, at the end of hostilities. The covered area is 425,000 sq. ft. and about 3,300 workers are employed. Key workers were sent from Birmingham to start production, and although a few remained at Cwmbran, the majority of the workers are local people, who had no previous experience of the company's products and had to be trained by the nucleus staff. The main production sections are concentrated in groups, and mass-production methods, with the maximum amount of mechanical aids, are used. Batteries of single-spindle and multi-spindle automatic lathes produce a large range of components. Presses, and numerous special-purpose machines, such as drilling machines for the simultaneous drilling of several holes, with automatic feed and return, are provided for the manufacture of a great number of small components. Brake linings are fixed to the shoes mainly by bonding, instead of riveting, though riveted linings can be supplied when required. For bonding shoes, the bonding material is sprayed on to the linings by a spray gun of orthodox pattern, and the shoe is shot-blasted to ensure cleanliness. The shoe is then placed in position on a special electrically-heated machine which gives the metal shoe an initial pre-heat. The lining is then placed on the shoe and held by an air-operated fixture while the machine applies heat for a pre-determined period. This machine is shown in the accompanying illustration. In the assembly of both brakes and dampers, the method used is to sub-assemble small components, which pass to a conveyor, either of the pendulum-tray chain type, or of the flat-belt pattern, the workers being, in most cases, seated. Final assembly is on the same plan, with air-operated or mechanical fixtures, nut-runners, and other mechanical equipment wherever possible. Tool-making requirements, which are considerable, are met by a large central tool room.

The company have paid particular attention to the training of apprentices, and have a very well equipped training centre at Cwmbran, with a full-time instructor in charge. Apprentices are engaged straight from school, and serve for six months on probation, provision being made for their discharge at the end of this period if they prove unsuitable. During the first six months, the boys are taught to use tools, and are employed on making articles which have no practical value except to teach the rudiments of engineering fitting. The standards laid down are strict. Boys are expected to produce, during their first six months in the centre, such things as cubes, which must be accurate to within 0·001 in., and to file a hexagon hole and fit a plug to it, which must fit accurately all six possible ways. After six months, the boys are put to work on more difficult jobs, and produce items of equipment for the works, such as gauges, jigs, and tools. At the end of two years, the boys leave the training centre, and spend the remainder of their apprenticeship in the works, beginning, in due course, to specialise in the work they choose, or for which they show special aptitude. Paid leave of absence is granted for the boys to attend a technical college. The apprenticeship scheme has proved so popular that there have always been more applicants than the training centre could accommodate.

The present Girling business originated when the Birmingham firm of New Hudson, Limited, gave up the manufacture of motor-cycles and bicycles in 1932, and concentrated on the machining of motor-car components. In the early 1930's the manufacture of the mechanical brake invented by Mr. A. H. G. Girling became one of the company's principal products. New Hudson, Limited, became an associate of Joseph Lucas, Limited, in 1943, when the name was changed to Girling, Limited, and the Bendix Company, another Lucas associate was incorporated. The Luvax Shock Absorber Company was added in 1944. Girling, Limited, now supply 52 per cent. of all the brakes fitted to British-made private cars, nearly 80 per cent. of those fitted to cars and lorries, and almost 100 per cent. of those on tractors. Brakes are also supplied to a number of manufacturers of special-purpose vehicles, such as cranes, dumpers, and trailers. Dampers are supplied to 16 car manufacturers, 20 commercial-vehicle builders, and 11 makers of motor-cycles.

FIFTY YEARS OF ELECTRIC TRACTION ON THE MERSEY RAILWAY.

A PROPOSAL to link Liverpool and Birkenhead by means of a tunnel under the River Mersey was made as long ago as 1825, but it was not until 1866 that Parliament granted powers for the necessary civil engineering works and the construction of a pneumatic railway. Delays occurred again, however, and it was actually only in 1880 that a contract was let for driving a small experimental tunnel under the river, in order to ascertain the nature of the ground forming the bed. Two shafts were sunk—one in Liverpool and one in Birkenhead—but after short lengths of tunnel had been driven from each end the contractor failed and the work had to be undertaken by another firm which eventually carried it to completion. The line was officially inaugurated by H.R.H. the Prince of Wales in January, 1886, and was opened to the public the following month. Originally, the railway extended from James Street station in Liverpool to Green Lane station in Birkenhead, but it was subsequently extended to Liverpool Central station in one direction and to Rock Ferry in the other. There was also a branch to Birkenhead Park. The main tunnel has an extreme width of 26 ft. and is 19 ft. high from the track rail-head to the top of the arch. It is lined with brickwork set in cement. In addition, there are smaller ventilation and drainage tunnels, which are joined together for a short distance at their lowest level.

Although the railway was well patronised at first, traffic subsequently fell off owing to the atmospheric conditions, and in 1900 it was decided to adopt the 650-volt direct-current third-rail system of electric traction. The conversion was carried out without interfering with the normal service and was completed on May 3, 1903. The present week, therefore, marks the 50th anniversary of the change from steam to electric traction. The Mersey Railway was the first line in this country to be so converted and, it may be added, was also among the first to employ colour-light signalling in conjunction with automatic train stops.

As the result of the grouping scheme of 1923, the Mersey Railway was taken over by the London Midland and Scottish Railway Company, and in 1938 through running between it and the lines of the latter system in the Wirral peninsula was inaugurated. This necessitated the provision of 19 three-car trains each consisting of a motor trailer and driving trailer. The original stock of the Mersey Railway was, however, retained in service.

THE LATE MR. B. C. JOY.—Mr. Bertram Charles Joy, M.I.Mech.E., son of David Joy, the locomotive valve-gear inventor, died recently. He was born in 1876 and received his training in his father's office. In the early days of the motor-car he was concerned with the design of petrol engines. He was chief designer to Simms Motor Units, Ltd., for whom he developed a magnetic oil filter, an air cleaner, a diaphragm pump and other components.

METAL WORKING MACHINE TOOLS.—We are asked to point out that the phrase "exclusion of direct-on-line starter of thermal overload protective type," which occurs in paragraph 21 on page 39 of the Anglo American Productivity Council's report on metal-working machine tools, should read "inclusion . . ." The error has, we understand, arisen from the different usages of the word "magnetic" in the United Kingdom and the United States, when applied to automatic contactor starters.

NEW WATERWORKS AT COVENTRY.—The official opening of the new waterworks at Coventry was performed by Sir Alfred Herbert on April 29. The new works are the major part of a scheme costing 2,500,000*l*., which is to supply 10,000,000 gallons of water a day to the Coventry City Water Committee's area. The water is obtained from an intake on the River Severn, near Upton-on-Severn, Worcestershire, 40 miles from Coventry, and there are two new reservoirs. One, at Bredon Hill, has a capacity of 1,500,000 gallons, and the other, at Meriden, near Coventry, holds 10,000,000 gallons. There is a purification plant at Strensham, near the intake. Duplication of the 40-mile pipeline remains to be completed before the full flow of 10,000,000 gallons a day is possible.

LABOUR NOTES.

NEW claims for large wage increases in the engineering and cognate industries appear likely to be forthcoming in the near future. Leaders of the 38 unions belonging to the Confederation of Shipbuilding and Engineering Unions decided, on April 29, at a meeting in London, to recommend that demands for an increase of 15 per cent. in the wages of all employees in the engineering, shipbuilding and ship-repairing industries should be presented to the Engineering and Allied Employers' National Federation and the Shipbuilding Employers' Federation as soon as possible. This recommendation is now being discussed by the full executives of the affiliated unions, and reports from these bodies will be available at the quarterly meeting of the Confederation in York on May 20, when a final decision is expected to be taken.

The suggested 15 per cent. increase, which would be applicable to the consolidated time rates for all classes and grades of adult employees in the engineering and shipbuilding industries, would be equal to an advance of about 20*s*. a week for skilled men and of 17*s*. 6*d*. a week for labourers, the exact amounts varying according to the different consolidated rates in operation throughout the country. The annual cost of the claims, if granted in full, would be in the region of 125 million pounds. There is a noteworthy difference between the new claims and those which have been put forward in these industries in the past few years, in that the suggested claims take the form of demands for an increase on a percentage basis, whereas previous claims have been for all-round advances for everyone. This departure from precedent is due, it is believed, to the feeling among craft unions that the granting of flat-rate increases has reduced the differentials between the pay of skilled and unskilled employees to a dangerously-narrow margin.

The constantly-increasing competition from abroad, especially from Germany and Japan, with which the engineering and shipbuilding industries are now being faced, seems certain to compel the employers' Federations to take a very firm stand with respect to the proposed new claims. Recent indications have been that there has been some decline in the general level of profits in these industries. An increase of 7*s*. 4*d*. a week for adult male employees in the engineering industry, and of 7*s*. 6*d*. a week for similar employees in the shipbuilding industry, were granted as recently as November last year. The unions' case, at that time, was based largely upon the increased cost of living. In this connection, it may be noted that the Ministry of Labour index of retail prices then stood at 138 for all items. The present level is 140, an advance of only two points. On the other hand, the unions had asked for 40*s*. a week all-round and it may well be that they will contend that the increases then conceded to their members were insufficient, having regard to the level to which the index had risen.

Proposals for wage increases figured prominently on the agenda of the annual conference of the national committee of the Amalgamated Engineering Union, which opened at Eastbourne on Monday. Almost every division of the union tabled a motion, in one form or another, asking for a claim for increased wages to be presented to the employers. Out of a total of 18 such motions, seven were in line with the recommendation of the Confederation of Shipbuilding and Engineering Unions, and asked for an advance of 15 per cent. Several divisions put forward proposals for all-round wage increases of varying amounts, while others suggested making claims for substantial sums, without mentioning any actual figure. One division wanted a claim for an increase of 20 per cent. to be put forward.

In all, no fewer than 398 resolutions were listed for consideration by the union's national committee. As in the past, they covered a very wide range of subjects and some were of special interest. There were several asking for the introduction of a forty-hour week into the engineering industry. One of the union's divisions urged that the Press should be excluded from meetings of the national committee. Another division asked that any question of disaffiliation from the Confederation of Shipbuilding and Engineering Unions should be decided by a ballot of the union's members.

Apart from any wage claim in respect of workpeople in the engineering and shipbuilding industries, demands are already being negotiated for increases for operatives in the agricultural and building industries, employees in the distributive trades, and for many of the lower grades in the Civil Service. It is estimated that, if granted in full, these claims would add a further 175 million pounds to the nation's annual wage bill. In this connection, a warning note was sounded by Mr. H. A. Watkinson, Parliamentary Secretary to the Ministry of Labour and National Service, in the House of Commons last week, when he stated that the easiest way for this country to price itself out of overseas markets would be by indulging in a continuing round of wage increases unrelated to higher production.

Similar concern is expressed by Mr. Arthur Deakin, C.H., the general secretary of the Transport and General Workers' Union, and a member of the General Council of the Trades Union Congress. Writing in the May issue of the *Transport and General Workers' Record*, the union's official journal, he warns trade unionists of the dangers of making the Budget proposals an excuse for presenting new and extravagant claims for increased wages. Members of the union know perfectly well, he states, that wage increases do not necessarily mean that living standards are improved, and that everyone is vitally concerned that nothing should happen that would add to the nation's difficulties in the export market.

What effect the new Budget will have upon the trade-union movement, in relation to its wage policy, will depend very largely upon the results that follow. Mr. Deakin adds that he wishes to make it quite clear that it should be no part of the purpose of the union's membership to do those things, or to pursue those policies, which would react to their disadvantage, merely because they dislike the Budget proposals or the colour of the Government.

Members of tug crews employed at Southampton have lost their claim for the payment for a minimum of seven hours, instead of four hours, when employed on night work. It may be recalled that the Southampton tugmen staged an unofficial strike last month in support of their wage demands. After three days, however, an offer from the employers of an increase of 2*d*. an hour for tugmen, and of 3*d*. an hour for masters and engineers, was accepted, and the men returned to work. At the same time, the two sides agreed that the claim in respect of payment for night work should be submitted to arbitration. It was announced in London last Saturday that the arbitrator appointed by the Ministry of Labour had rejected the claim, and that the men concerned, who belong to the Transport and General Workers' Union, would meet later this week to discuss the decision.

The retirement of Sir Alexander Ramsay from the position of director of the Engineering and Allied Employers' National Federation was announced on May 1. Sir Alexander, who is 66 years of age, and has held that office for 18 years, has been an official of the Federation for over 32 years. During that time, he has been engaged in negotations with trade unions on some of the largest wage claims to be submitted in this country.

Some 60,000 employees in the engineering, supplies, and factory departments of the Post Office are expected to benefit from an award of the Civil Service Arbitration Tribunal, the terms of which were announced last Friday by the Post Office Engineering Union. Adult male employees will receive an increase of 8*s*. a week, adult women 6*s*. 6*d*., and juveniles 4*s*. These increases will be effective as from January 1, this year.

CAST-IRON HEATING PIPES FOR OIL TANKERS.

COLVIN-SMITH, LTD., GATESHEAD-UPON-TYNE.

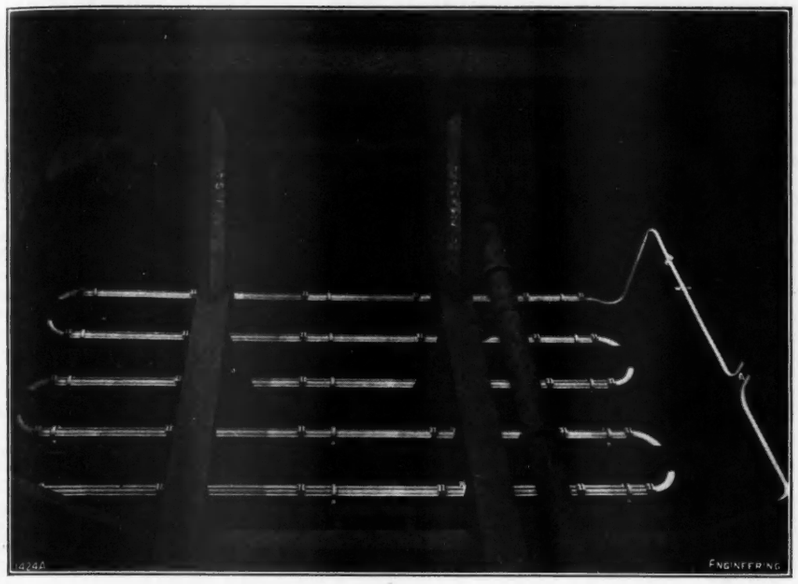


FIG. 1. TYPICAL INSTALLATION IN A CARGO TANK.

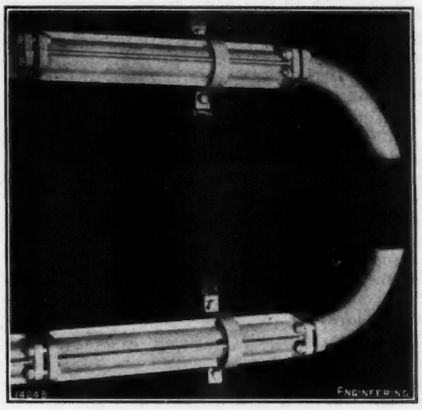
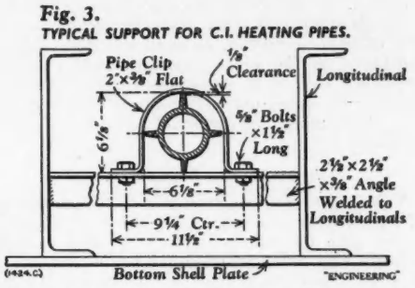


FIG. 2. END CONNECTIONS AND FIXINGS.



CAST-IRON HEATING PIPES FOR OIL TANKERS.

FOR crude oils to be of a sufficiently low viscosity to be economically pumped, they must be at a temperature approaching 140 deg. F. The oils are at this temperature when they are pumped into sea-going tankers and, in order that they may be pumped out at the end of the journey, it is necessary either to maintain this temperature or to reheat the oil prior to unloading. To this end, steam heating grids are installed in the tanks.

It has been customary for these heating grids to be of steel, but the conditions brought about by the alternating submersion in oil and sea-water ballast, enhanced by the local high temperature and the sulphur content of the oil, caused rapid corrosion of the steel heating grids. As a result of this rapid corrosion, the replacement of these grids, or parts of them, has had to be undertaken every two years, and instances have been experienced where the entire heating system has had to be replaced within an even shorter period. The cost of this periodical replacement has, in the past, been accepted as an unavoidable maintenance charge, but the present high level of costs, however, coupled with the difficulty of steel supplies and the financial loss incurred while the tanker was in port undergoing repairs, made it imperative that other methods of heating should be employed. The greater resistance of cast iron to corrosion than that of steel has provided a solution to the difficulties. At the suggestion of Mr. John Lamb, O.B.E., Research and Development Manager for the Anglo-Saxon Petroleum Company, Limited, the use of cast iron and some modification to the arrangements of the grids have been tried out and successful operating conditions achieved.

A typical view of a heating grid of cast-iron piping is shown in Fig. 1, herewith, and details of fixings are shown in Figs. 2 and 3. The particular section of pipe being used can be seen by reference to Fig. 3, which clearly shows the finned section that has proved so successful. With the change from steel to cast iron, some method had to be found for gaining a stronger section that would off-set the inherent lower strength of the cast iron, and the fins not only provided this additional material but provided an increased heating surface for unit length of pipe. A second innovation made with the change-over from steel to cast iron has been to increase the size of the pipe, simultaneously reducing the number used; this has had the advantage of making it far easier to clean out the tanks but, at the same time, has achieved the tanker-owners' specified requirement of 1 sq. ft. of heating surface for between each 100 and 120 cub. ft. of tank capacity. (The section employed has a heating surface of 1·66 sq. ft. per linear foot of pipe.)

The supply and installation of these cast-iron heating grids are undertaken by Colvin-Smith, Limited, Team Valley, Gateshead-on-Tyne. Particular care has to be taken when fitting the grids in order that each pipe shall be free to take up any expansion or contraction; mobile teams of fitters are therefore sent from the company's works to install the grids at the various shipyards concerned, so that a high standard of workmanship is maintained. Clearances of ⅛ in. are carefully maintained between the tips of the fins and the hoop clips to ensure that temperature movements are readily taken up without imposing any undue strain on the cast iron. At the end connections, where considerable thermal movements are inevitable, as well as in the risers between the grids and the main supply and return pipes to the boiler, the use of steel pipes has been retained, although experiments are at present in hand with alloy cast irons that exhibit a relatively high degree of ductility, with a view to total replacement of the steel by cast iron. Cast-iron grids have now been used for rather more than six years and nearly 100 tankers have been so equipped, giving satisfactory service. The extended life of the cast-iron heating grids has more than off-set their somewhat higher initial cost.

THE FEDERATION OF BRITISH INDUSTRIES.

WHEN the Federation of British Industries was formed in 1916, its aim was the "encouragement, promotion and protection of British industries of all kinds." That it has served those purposes well is clearly indicated by the fact that its report for 1952 is able to record that in that year there was a net gain in membership of 245 individual firms. At the end of the year, the total membership consisted of 6,603 firms and 285 trade associations.

The Federation does not concern itself with rates of pay or labour conditions, but may claim to represent and speak for industry in almost every other matter affecting its interests. One field in which it is particularly valuable that an authoritative body should exist, able to speak for industry as a whole, is that covered by Government activities in connection with economic policy, taxation and planning legislation. A particular service the Federation can render to individual members in connection with matters of this kind is to advise them in what way new regulations and controls may affect their interests. Such advice may be of a technical kind, and the report records, for instance, activities in connection with river pollution and trade effluents. It is important that River Boards and local authorities should not impose conditions with which it is impossible for industry to comply. Industry being spread throughout the country, there are in many cases local matters which demand local consideration, and a valuable feature of the whole organisation is the existence of ten Regional Councils which can pay particular attention to matters arising within their areas.

The number of special committees and outside bodies on which the Federation is represented is much too great for a list to be given, but in matters of special engineering interest, electricity and gas supply, productivity and education may be mentioned. Industry, particularly the engineering industry, is very closely concerned with overseas trade, and the Federation is in a position to advise, and in some cases to bring pressure, in connection with regulations and restrictions imposed by other countries which may have unfavourable effect on British trade. As the Federation is represented in 92 foreign countries, full information is available about trade conditions and prospects in any part of the world, except in the area represented by Russia and the countries under her control.

BUILDING PLANT EXHIBITION.—The Ministry of Works, Lambeth Bridge House, London, S.E.1, has organised an exhibition of building plant and equipment, which will be held on the Goose Fair site at Nottingham from Thursday, September 3, to Wednesday, September 9. Many of the machines exhibited will be shown in action. The exhibition will occupy an area of 200,000 sq. ft. and there is an additional area of about 20,000 sq. ft. which is available for the demonstration of such machines as tractors, scrapers, earth augers and powered barrows.

BOILER-WATER TREATMENT TO PREVENT CORROSION.*

By U. R. EVANS, Sc.D., F.R.S.

THE author of this paper is not a specialist on boiler problems; nevertheless, it is possible that there may be some slight value in a paper which surveys them from the standpoint of fundamental corrosion science—at least, if it is read with papers by other authors, who approach the subject from different angles.

In the present paper, it has been necessary to rely too much on experimental data obtained at 100 deg. C. or lower, in discussing what is likely to happen at boiler temperatures; this necessity is regretted and any uncertainties thus introduced should be borne in mind by the reader. It is hoped that laboratory experiments, rather similar to those of Thiel and Luckmann, and of Gould, but carried out at higher temperatures, may become available in the future.

Boiler water receives treatment in order to prevent the formation of heat-obstructive scale, corrosion of the steel, and carry-over of matter by the steam. The avoidance of scale, if achieved, will itself do much to lessen chemical destruction, since oxidation on the fire side and, to a less extent, wet corrosion on the water side, becomes accelerated when there is overheating. Nevertheless, the problem of scale formation, as such, will not receive treatment in the present paper, which will be concerned only with the question: can we, by treating the water, prevent chemical destruction of the steel under conditions of normal thermal operation?

FUNDAMENTAL PRINCIPLES.

T. V. Arden† has found that the solubility product of ferrous hydroxide is $2{\cdot}4 \times 10^{-14}$, which is much higher than the figures obtained by some earlier workers who failed to remove traces of oxygen; thus the activity of Fe^{++} in neutral water (pH=7) is $\frac{2{\cdot}4 \times 10^{-14}}{10^{-14}}$, or 2·4, which is $10^{0{\cdot}38}$. The potential of the electrode $Fe \mid Fe^{++}$ (normal activity) is $-0{\cdot}441$ volt on the hydrogen scale, so that the E.M.F. of the cell hydrogen | neutral water saturated with $Fe(OH)_2 \mid Fe$ exerts an E.M.F. equal to $-(7 \times 0{\cdot}058) - (-0{\cdot}441 + (0{\cdot}38 \times 0{\cdot}029))$ volt; this is 24 millivolts, acting in such a direction that iron tends to enter the liquid, displacing hydrogen. That small E.M.F., provided that there is no formation of complexes, is independent of pH value, as pointed out by J. C. Warner.‡ If the liquid is made alkaline, the potential $H_2 \mid H^+$ is shifted by 58 millivolts per pH unit, at room temperature, but the reduced solubility of ferrous hydroxide will shift the potential $Fe \mid Fe^{--}$ by the same amount. Any action of alkali in preventing the evolution of hydrogen by the action of water on iron must be ascribed, not to a diminution of the driving force, but to the production of conditions more favourable to film formation.

Such film formation, however, clearly occurs, even in neutral water. The curves obtained by A. Thiel and H. Luckmann§ for the evolution of hydrogen by iron in water about 100 deg. C., shows that evolution is fast at first, but soon becomes slow (Fig. 1). A. J. Gould‖ studied the behaviour of steel towards water in sealed tubes containing no oxygen. He found that, after 76 days at 100 deg. C., the destruction of metal (as measured by the loss of weight after removal of oxide) was only about 0·5 mg. on specimens measuring $7{\cdot}5 \times 10$ cm.; before removal of oxide there was a gain in weight, suggesting a film of appreciable thickness. The film, after transfer to celluloid, was found to be magnetite; it is not inconceivable that it had been ferrous oxide on the metal and became oxidised during the transfer, but it seems more likely that it was already magnetite when adhering to the metal. Probably, the ferrous hydroxide formed by the action of boiling water on iron

$$Fe + 2H_2O = Fe(OH)_2 + H_2$$

is changed to magnetite by Schikorr's reaction*

$$3\,Fe(OH)_2 = Fe_3O_4 + 2H_2O + H_2.$$

J. N. Wanklyn† found that Schikorr's reaction does not occur readily in the absence of a catalyst, but that it takes place if metallic nickel, copper or platinum are present. Although the result was not verified on an iron surface, it seems likely that magnetite will slowly be deposited on steel from boiling water containing ferrous hydroxide; or that, if a film of solid ferrous oxide or ferrous hydroxide has been deposited on steel, it will sooner or later change to magnetite, with the evolution of hydrogen. Whatever the exact composition of the film, the cessation of hydrogen evolution is easily understood, provided that the film is continuous over the surface. Anything which favours the formation of closely spaced nuclei (whether of magnetite, ferrous hydroxide or ferrous oxide) on the surface will promote the formation of a continuous protective film, and, consequently, the cessation of attack. Conversely, anything which favours the precipitate of oxide or hydroxide at a distance from the metal will encourage the continuation of attack.

Fig. 1.

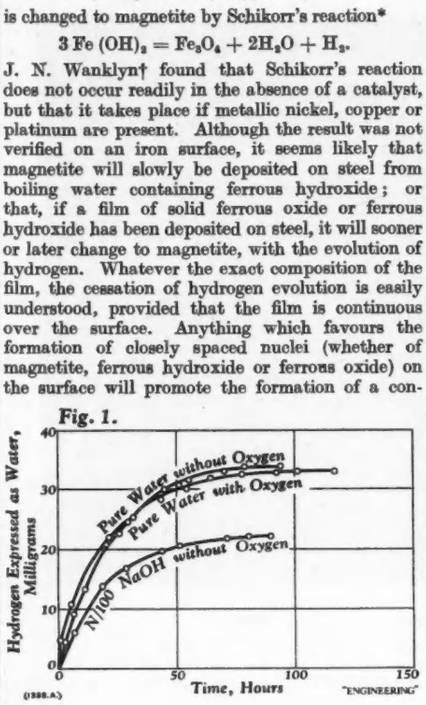
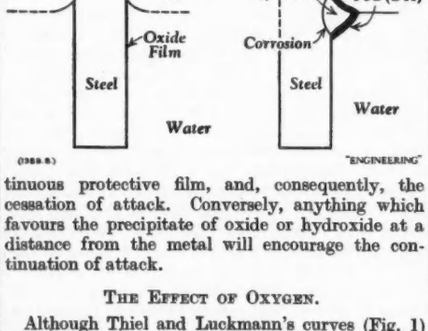


Fig. 2.



THE EFFECT OF OXYGEN.

Although Thiel and Luckmann's curves (Fig. 1) show that the presence of oxygen does not increase the hydrogen evolution, it causes much corrosion of another type. Gould compared the behaviour of iron standing partly immersed in boiling water with only oxygen-free steam above the liquid, and iron standing partly immersed in boiling water with access of air to the space above the liquid. In absence of oxygen, attack soon became slow—doubtless through film-formation on the metallic surface, the weight loss being about 0·5 mg. after 76 days. When air had access, the weight loss was 365·2 mg. in the same period. Probably, part of the ferrous hydroxide formed near the waterline passed into solution, and, meeting dissolved oxygen, was transformed into magnetite (Fe_3O_4) or hydrated ferric oxide ($Fe_2O_3 \cdot H_2O$ or FeO(OH)) at a slight distance from the metal (see Fig. 2, herewith). Solid formed at a distance cannot prevent attack, and the destruction of dissolved ferrous hydroxide prevents the attainment of the high state of supersaturation with ferrous hydroxide which would be needed for the formation of a continuous film of ferrous hydroxide or ferrous oxide on the metal itself; when once it has started, any magnetite formed by Schikorr's reaction will probably be deposited on the existing magnetite at a distance from the site of attack in preference to the formation of fresh nuclei. This explains why Gould found that, when oxygen was present, the crust of magnetite formed near the waterline adhered to the metal only at a few points. The magnetite here was mixed with hydrated ferric oxide (rust); both compounds appeared to have been formed at the water-air interface, where oxygen is present, rather than the metal-water interface. When this semi adherent crust was removed, the iron was found to be deeply pitted and trenched.

In working boilers, the temperature will be higher, but probably the same principles apply; the supply of oxygen should be insufficient to form rust, but it may be sufficient to bring the place of formation of magnetite to a slight distance from the metal, which locally develops no protective film, so that pitting arises. Clearly, if the oxygen reaches certain areas of the boiler surface only, other parts being screened, conditions become particularly favourable for attack, which will be most intense when the screened area is small. G. P. Acock, T. Dennison, P. T. Gilbert and R. S. Thornhill* write that "Corrosion is sometimes found under scale or other deposits. . . . The reason is probably differential aeration, i.e., the shielded metal, receiving a poorer supply of oxygen than the areas surrounding it, becomes anodic and is attacked." They add that corrosion below deposits may also be due to the concentration of alkali and other salts; temperatures and concentration may locally be reached at which attack becomes rapid. M. Werner† also discusses corrosion below deposits in high-pressure boilers. A. A. Berk‡ assigns an important role to the ferrous iron introduced from the pre-boiler system in producing intensified attack at screened areas.

THE EFFECT OF ALKALI.

By increasing the $(OH)^-$ activity, the solubility of all the oxides and hydroxides is reduced, and the degree of supersaturation set up in the liquid very close to the metal is raised. This will clearly favour the production of closely-spaced nuclei of one of the three compounds, and promote the formation of a protective film; thus alkali additions to boiler-water may overcome the bad effect of oxygen. Gould's laboratory measurements, in the presence of air, record lower weight losses in N/100 sodium hydroxide than in pure water. In the absence of oxygen, his results permit of no definite conclusions regarding the effect of alkali, but Thiel and Luckmann's curves (Fig. 1) suggest that the oxide film becomes protective after a smaller evolution of hydrogen (i.e., after a smaller destruction of metal) in dilute alkali than in neutral water. These observations accord with practical experience; the subject has received convenient treatment by I. G. Slater and N. L. Parr.§

THE EFFECT OF METALLIC COPPER.

Boiler water often contains copper, derived from condenser tubes or other parts outside the boiler proper which consist of copper or copper alloy. This will not necessarily be harmful. Sometimes the copper is precipitated as oxide, basic carbonate or phosphate, and passes out with the sludge. In other cases, the water contains dissolved copper salts without metallic copper being thrown down on the steel. In an acid solution of a copper salt, which should not exist in a boiler, iron would pass into solution, precipitating metallic copper. In an alkaline solution, copper ions can normally exist only at very low concentrations, and, in any case, the iron (becoming passive, owing to film formation, as already explained) is unlikely to precipitate metallic copper. It seems, however, that certain waters, containing ammonia or ammonia derivatives introduced by sewage pollution, can attack copper or copper alloys (oxygen probably facilitating the reaction) and yet leave the iron active. Perhaps chlorides play a part in keeping the iron

* Paper presented at the "Journées internationales d'Études des Eaux de Chaudières," organised at Liége on May 4 to 6, 1953, by the Centre Belge d'Étude et de Documentation des Eaux. Abridged.

† *Jl. Chem. Soc.*, 1950, page 883.

‡ *Trans. Electrochem. Soc.*, vol. 55, page 287 (1929).

§ *Korrosion und Metallschutz*, vol. 4, page 169 (1928).

‖ *Jl. Iron and Steel Inst.*, vol. 155, page 195 (1947).

* G. Schikorr, *Zeit. Electrochem.*, vol. 35, page 65 (1929); and *Zeit. Anorg. Chem.*, vol. 212, page 33 (1933).

† *Nature*, vol. 162, page 27 (1948).

* *Iron and Steel Inst. Special Report* No. 41 (1949).

† *Werkstoffe und Korrosion*, vol. 3, page 333 (1952).

‡ Private communication to the author, February 24, 1953.

§ *Proc. I.Mech.E.*, vol. 160, page 341 (1949).

active. R. L. Rees* considers that carbon dioxide can attack copper in presence of oxygen, even if ammonia is absent; attack is more rapid when it is present. In such circumstances, iron can enter the liquid, precipitating copper in a metallic form, sufficiently clean to act as a catalyst for Schikorr's reaction; Wanklyn found that metallic copper catalysed that reaction efficiently, even at room temperature. If this occurs in a boiler, then ferrous hydroxide, produced by the reaction of water on iron at breaks in the magnetite scale, will deposit fresh magnetite, not on the steel exposed at the break (which, in that case, would be repaired) but on an adjacent speck of metallic copper. Thus the magnetite round the copper will thicken, but, when the original copper has been buried, more may be deposited, and thus the process goes on, producing a pit surrounded by very thick magnetite scale with embedded specks or microscopic flakes of metallic copper.

Pitting associated with thick magnetite scale containing metallic copper has been observed at power stations.† The features of this type of corrosion are: (1) the copper is often deposited upon the magnetite and also on bare steel at places where the steel is uncorroded; (2) specks of copper are included in the magnetite and, indeed, there may be layers of metallic copper laminated in between layers of magnetite; (3) at places where there is corrosion, the magnetite, although clinging to the steel at a few points, is not always in continuous contact with the steel—a cavity often exists between the two, although sometimes pits are found which appear to be tightly plugged to the bottom; and (4) the magnetite is laminated and can grow to considerable thicknesses near the points of attack.

These facts suggest that iron is passing into solution at certain points, giving a solution of ferrous hydroxide, which becomes converted to magnetite by the Schikorr reaction—not, for the most part, at the point of formation (where it would produce a protective film) but preferentially on the copper specks; when these become embedded in the freshly deposited magnetite, fresh copper is deposited upon the magnetite as cathode, steel exposed at the point of corrosion providing the anode. The scheme is suggested in Fig. 3, herewith, which is purely diagrammatic and may not represent the true geometry of the system.

The interpretation sketched above is put forward tentatively, but does serve to explain the facts known to the author without *ad hoc* assumptions. Other explanations‡ are possible. Berk, for instance, considers that the hydrogen produced by the Schikorr reaction during the partial oxidation of ferrous iron introduced with the feed-water can and does precipitate metallic copper, which, in certain cases, may promote carbuncle pitting.

Main Requirements for Boiler Water.

If we leave aside the dangers involved in the presence of copper, the two main requirements for avoiding corrosion are the absence of oxygen and an adequate reservoir of $(OH)^-$. To-day, the bulk of the oxygen is commonly removed by thermal methods, which also take out the nitrogen, but it is generally believed that chemical methods are needed to eliminate the last traces. If this is true, it would seem desirable to improve the thermal methods, so that they can remove the whole of the dissolved gases. Chemical methods, whether based on sulphite or hydrazine, do not remove the nitrogen; the hydrazine method may even increase it. Nitrogen pockets are often assumed to be harmless, although there seems to be no proof of this. The use of sulphite increases the dissolved solids, may produce sulphur dioxide if the water should become temporarily or locally acid, and may give rise to hydrogen sulphide, in certain circumstances not clearly defined; both of these compounds can be dangerous.

An adequate hydroxyl reserve is not necessarily the same thing as a high *p*H value, since a good buffer system can maintain a supply of $(OH)^-$ ions, replenishing very rapidly the $(OH)^-$ ions used up in film repair, even though the *p*H value is not very high. Provided that the replenishment rate by a buffer-system can be regarded as sufficient, the plan of maintaining the required $(OH)^-$ content by the presence of sodium hydroxide (or of carbonate, which becomes hydroxide) would seem to be illogical, although commonly used to-day. However, the main objections to reliance on sodium hydroxide as the source of OH^- are the dangers of carry-over and of cracking.

The Action of Concentrated Alkali on Metal.

Most metals are dissolved by acids forming soluble salts; in liquids of *p*H value somewhat above 7, where the corrosion-product would be a sparingly soluble oxide or hydroxide, there is little attack, but in definitely alkaline solutions attack is again met with in many cases; thus zinc dissolves to form a zincate, aluminium as an aluminate, tin as a stannite and lead as a plumbite. Iron differs from the four metals just mentioned in that a really high concentration of alkali and a slightly elevated temperature is needed for the formation of sodium ferroate (Na_2FeO_2)—which corresponds to sodium zincate (Na_2ZnO_2). The alkali concentrations

Fig. 3.

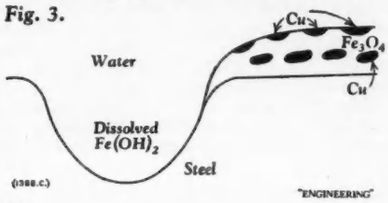
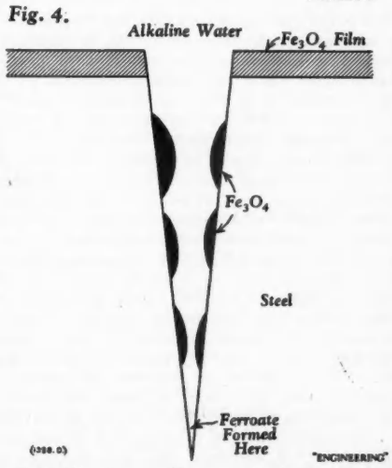


Fig. 4.



needed will not normally occur in the body of the water in a boiler, but if there is a leakage path, as may exist at imperfect riveted joints or imperfect flanged couplings, which allows the escape of steam but not of water, alkali may accumulate and high concentrations may be reached. Some authorities consider that similar concentration can occur in absence of leakage, e.g., below deposits, or even on clean surfaces, when bubble formation is rapid, in the crevices formed between bubble and metal.

The reaction of iron with hot concentrated sodium-hydroxide solution would excite less alarm if it were well spread out. Unfortunately, with steel under tensional stress, there is frequently a preferential attack along the grain boundaries, and cracking occurs. The metal is apparently attacked at the tip of a crack as it advances into the metal, forming a solution of sodium ferroate; at a short distance from the place of formation, the ferroate decomposes, throwing down magnetite, either with evolution of hydrogen, by a reaction of the Schikorr type, or through the action of oxygen or an oxidising agent,

$$3Na_2FeO_2 + 4H_2O = 6NaOH + Fe_3O_4 + 2H$$

$$3Na_2FeO_2 + 3H_2O + O = 6NaOH + Fe_3O_4.$$

Thus magnetite appears in the cracks, although at an appreciable distance from the point of formation of the ferroate, as suggested diagrammatically in Fig. 4, herewith.

The sodium ferroate may decompose at a distance from its point of formation either because it becomes diluted (the ferroate is only stable in presence of excess of alkali) or because it meets with oxygen. C. D. Weir* observes that the large fissures are filled with ferroso-ferric oxide, with smaller amounts of ferrous oxide, but that associated with each large fissure is a network of very fine subsidiary intergranular cracks, many of which appear to be free from corrosion products. E. W. Colbeck, S. H. Smith and L. Powell† state that there are only slight signs of thin oxide inside the fine intergranular cracks, although there is a crystalline deposit of black magnetic oxide outside the crack; they describe, however, a second type of straight, blunt-ended transgranular cracks which are filled with corrosion products. Berk states that many cracks which appear to be free from magnetite are found to contain it when examined at higher magnification. He thinks that magnetite is formed at the tips of the cracks, and that the attack continues only because magnetite is brittle.

To the author, it seems more likely that magnetite is a secondary product, deposited from solution at a distance from the point of attack—the tip of the advancing crack. Because of the point of formation, the magnetite cannot stop the attack. If, however, an oxidising agent more soluble than oxygen were supplied in sufficient quantity to convert ferroate into magnetite at the point where the ferroate is formed, the attack might cease. This may be the cause of the prevention of caustic cracking brought about by the presence of nitrate, which furnishes oxidising anions capable of moving rapidly towards the anodic region (the tip of the advancing crack) under the electric potential gradient, whereas the uncharged oxygen molecules can only move slowly by diffusion under a very low concentration-gradient; but the explanation is put forward tentatively.

Whether ferroate is changed to magnetite by the adsorption of oxygen or the evolution of hydrogen, the sodium hydroxide is regenerated in full; but, in the Schikorr type of reaction, atomic hydrogen may enter the metal, increasing the inter-crystalline fragility. There is no definite proof that this occurs, but the idea of local embrittlement caused by hydrogen-formation at the crack-tips causing local embrittlement would agree with views now developing for other cases of stress-corrosion cracking; it should be noted that the steel between the cracks is not brittle. It seems unlikely that hydrogen produces cracking by converting carbon to a hydrocarbon gas—as seems to be claimed by C. A. Zappfe.‡

Nitrate Cracking and Caustic Cracking.

Surprise is sometimes expressed at the fact that nitrates, which tend to prevent cracking in highly alkaline liquid, can cause cracking under slightly acid conditions; steel stressed in a hot concentrated solution of the nitrate of a weak base (which solution will react slightly acid) suffers intergranular cracking, leading rapidly to fracture. However, analogous cases could be cited: small amounts of chromates prevent corrosion in neutral or weakly alkaline liquids, but accelerate corrosion by dilute sulphuric acid; indeed, most oxidising agents are cathodic stimulators and anodic inhibitors, and the alleged paradox has no reality.

The relation between nitrate-cracking and caustic-cracking deserves study. Steel in a boiling ammonium-nitrate solution becomes covered with a layer of magnetite, which would be protective if it were continuous, but usually it becomes broken in places, and the steel there exposed suffers intense attack; the combination of large cathode (the scale) and small anode (the steel exposed) favours intensity, for well-known electrochemical reasons. If the steel is one in which the intergranular layers are more susceptible than the grains themselves, and if it is kept under tensile stress, the attack will constitute cracking.

The fact that a nitrate solution which produces a protective magnetite coat over the outer face of the metal, fails to produce protection at the tip of the advancing crack may be due to a lower concentration (due to a lower rate of replenishment) within the

* Private communication to the author, February 24, 1953.

† E. W. F. Gillham and R. Ll. Rees, *Bull. Centre Belge d'Etude et de Documentation des Eaux*, 1951, page 16.

‡ R. Ll. Rees, *Chem. Ind.*, 1951, page 1198.

* *Trans. I.E.S. Scot.*, vol. 92, page 163 (1948).

† *Proc. I.Mech.E.*, vol. 149, pages 63, 95 and 112 (1943).

‡ *Trans. A.S.M.E.*, vol. 66, page 81 (1944).

crack; perhaps, also, the stress keeps breaking any obstructive oxide formed at the tip of the crack. However, not all steels possess the intergranular paths of susceptible matter needed for nitrate cracking. R. N. Parkins* finds that steels containing carbide particles along the grain-boundaries are susceptible to nitrate-cracking; by applying a heat-treatment which produces such a structure, he has converted a resistant steel into a susceptible one. The attack does not fall upon the carbide particles, but upon the ferrite along the grain boundaries, which is considered to be kept in stress owing to the difference between the coefficients of thermal expansion of carbide and ferrite respectively. This highly stressed ferrite at the grain boundary will suffer anodic attack in preference to the less stressed grain interiors† and the crack will advance mainly along intergranular paths running roughly at right angles to the direction of the applied stress—explaining the facts observed.

Caustic cracking has some points in common with nitrate cracking, but some important differences. The magnetite layer covering the face of the steel probably acts as the big cathode at the outset, with the tips of the incipient cracks as the small anodes. However, the deposition of magnetite in the cracks as they advance may serve to provide new cathodes relatively close to the anodes, so that the resistance of the corrosion cells is kept low—an occurrence favourable to the advance of the cracks. Moreover, the attack appears to fall not on the ferrite, but on the carbide—particularly in the pearlite regions—an important fact observed independently by C. D. Weir‡ and by G. A. Cottell.§ An explanation can be suggested. The dioxide of carbon has pronounced acidic properties, while the oxides of iron have only feeble acidic properties; thus attack by alkali on a phase which can furnish sodium carbonate as well as ferroate may be expected to proceed more readily than one which would furnish ferroate alone.

For this reason, the steels which are most resistant to nitrate-cracking will not necessarily resist caustic-cracking; indeed, although steels differ among themselves in liability to cracking in caustic, none are immune from the trouble. On the other hand, caustic cracking seems to occur more easily when there is a rather complicated non-uniform stress condition—as brought out by Colbeck, Smith and Powell, *loc. cit.* Badly aligned rivets produce conditions favourable to caustic cracking, perhaps because they favour leakage and hence concentration of sodium hydroxide. The packing pieces of double butt-strap seams sometimes crack to a surprising extent, and unwise caulking can produce a non-uniform stress very conductive to caustic cracking—points emphasised by Cottell.

The Schroeder-Berk embrittlement detector,‖ a device which can be fitted to a working boiler and sets up cracking conditions by concentrating the water through evaporative leakage in contact with a stressed-steel specimen, has practical value for distinguishing a water capable of producing cracking from one which is not immediately dangerous.

Avoidance of Caustic Cracking.

If boiler water is given its necessary alkalinity by the presence of sodium hydroxide, it may be only a matter of time before leakage locally raises the concentration of caustic to a dangerous level. In practice, it is found that caustic cracking often does take a long period to develop; if there is no leak, it may never develop at all. It is impossible to state a critical alkali concentration below which a boiler water can be regarded as "safe"; however low the concentration may be in the body of the water, the risk remains that a dangerous level may ultimately be reached in the seams.

If, however, the water contains sodium phosphate with a ratio of Na_2O/P_2O_5 slightly lower than that corresponding to a solution of pure Na_3PO_4, then a concentration of $(OH)^-$ can be maintained by hydrolysis in the body of the water, apparently sufficient to prevent ordinary corrosion, but without risk of excessive $(OH)^-$ concentration in seams or recesses; for, when once concentration has reached the level at which solid Na_3PO_4 is thrown out, the concentration of $(OH)^-$ cannot rise further. Practical experience has shown that the maximum $(OH)^-$ concentration thus reached is below the dangerous limit. In general, it is not necessary to add trisodium phosphate. If the water is already alkaline, common sodium phosphate ($Na_2HPO_4 \cdot 12H_2O$) or Calgon ($NaPO_3$)$_n$, which changes to NaH_2PO_4 under boiler conditions, may be added in appropriate amount. Berk* gives favourable accounts of the employment of this method in the United States of America—where it was worked out; P. Hamer and C. D. Weir† discuss its application in Great Britain.

Other methods for preventing caustic cracking include nitrate treatment, which appears to have met with considerable success on American railways; a tentative explanation has been offered above: Weir and Hamer, basing their recommendation on American experience, suggest that the ratio of $NaNO_3$ to total alkalinity, expressed as NaOH, should be 0·4. Treatment with quebracho or other tannin has also been helpful, the ratio being again 0·4.

The Sulphate-Ratio Controversy.

The belief that caustic cracking can be controlled by maintaining the ratio of Na_2SO_4 to alkalinity above a certain value was put forward in the United States many years ago, on evidence which to-day appears somewhat unconvincing. Lately, the method has been widely advocated in Great Britain, though simultaneously faith in its efficacy has faded in its country of origin—particularly in railway circles, where some sharp criticism has been expressed. Thus a report issued by the American Railway Engineers' Association‡ states: "On the railroads it was found that embrittlement was occurring in boilers where high sulphate-hydroxide ratios were maintained and no embrittlement was being experienced with feed water containing no sulphate and a very high sodium carbonate content. The sodium carbonate hydrolysed into sodium hydroxide in excessive amounts at boiler temperature. . . . Due to the fact that the sulphate-hydroxide ratio maintained in steam boilers was found worthless as an inhibitor in railroad service, . . . it is the opinion of your Committee that the railroads should disregard the sodium-sulphate/hydroxide ratio recommendations, as outlined in the American Society of Mechanical Engineers Boiler Code of 1940. . . ."

They recommend the properly supervised and controlled use of sodium nitrate or lignin in water known to have embrittling tendencies; proper workmanship, resulting in tight boiler seams; and the installation of embrittlement detectors on boilers operating in suspected-water districts. The effectiveness of nitrate (and, to a less extent, quebracho) in locomotive and stationary boilers is shown by recent figures supplied by Berk.

The sulphate-ratio method is supposed to work (to quote Weir and Hamer) "either by the deposition of solid sodium sulphate on the highly stressed parts of the boiler-plate or by plugging a seam"; the same authorities suggest that it may sometimes be calcium sulphate which forms the protective layer. Statistical analysis of the results obtained with the sulphate-ratio method by Weir§ appears to indicate that it is without value. Weir's analysis, however, has been criticised on the grounds that the classification of waters as cracking and non-cracking was made by means of the Schroeder-Berk detector—not by direct observation on working boilers; it has been argued that, however valuable the detector may be for appraising the essential cracking powers of a water, it is less suitable for estimating the plugging properties.

A high-sulphate ratio may be obtained by keeping the $(OH)^-$ low as well as by keeping the $(SO_4)^{--}$ high. It is generally agreed that high $(OH)^-$ is dangerous, although opinion varies upon the question as to whether $(SO_4)^{--}$ is beneficial. In early days, it was not unusual to treat a dangerous water, rich in OH^-, with sulphuric acid or magnesium sulphate; apparently with some success, provided that the additions were made with restraint, since some OH^- is needed to prevent other types of attack. Here any beneficial effects could be attributed to the lowering of the $(OH)^-$ rather than the increase of the SO_4^{--} concentration.* For some reason, however, it came to be believed that a high $\frac{(SO_4)^{--}}{OH^-}$ ratio (rather than a low value for the absolute OH^- concentration) was the essential criterion for safety; and boiler owners to-day are being recommended to add sodium sulphate, which increases the $(SO_4)^{--}$ concentration without greatly affecting the $(OH)^-$ concentration. It is confidently asserted in this country that such a treatment usually prevents cracking where otherwise it would occur, although it is now admitted that the method sometimes fails. In a plant where careful and continuous observations show that, in point of fact, water thus treated is not producing cracking, it would be rash to suggest a change in procedure; but it would be impossible to feel confident that the same treatment applied in a new plant would also prevent cracking.

The British Electricity Authority are proposing to use, at some power stations, the sulphate-ratio method along with the nitrate method, thus establishing two lines of defence. In the present state of knowledge, this seems a prudent course. If the chance of cracking in the doubly-protected boiler is the product of the chances in two boilers singly protected by each of the methods, it is the product of two small quantities and therefore negligible. However, this argument is only valid if the protective mechanisms are so dissimilar that there is no correlation between the incidence of breakdowns under the two processes; the doubts which arise in deciding the question of possible correlation underline the practical importance of greater understanding of the manner in which these protective processes operate.

Common Features of All Types of Corrosion.

Each kind of trouble discussed above can be related to a single cause. An oxide (usually magnetite) which, under normal working, would be produced as a continuous adherent protective skin, capable of hindering further attack, is, under exceptional conditions, thrown down at certain points at an appreciable distance from the surface, where it cannot protect the steel. Various unfavourable factors may produce this undesired result. The iron may pass into solution as ferrous hydroxide and be transformed to magnetite a short distance away, at a point to which oxygen has access; or it may pass into solution as ferrous hydroxide and be transformed to magnetite (with hydrogen evolution) at a short distance, where metallic copper—a catalyst for the Schikorr reaction—has been deposited; or it may pass into solution in strongly alkaline crevices as sodium ferroates, which may be transformed to magnetite at a short distance, where the liquid becomes diluted or where oxygen is available.

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* *Jl. Iron and Steel Inst.*, vol. 172, page 149 (1952); and *Chem. Ind.*, 1953, page 180.

† Cf. M. T. Simnad and U. R. Evans, *Trans. Faraday Soc.*, vol. 46, page 175 (1950), who discuss the effect of annealing on electrode potential.

‡ Discussion of *Boiler Symposium, Soc. of Chem. Ind.* Corrosion Group, 1952.

§ *Tech. Rept. of Brit. Eng., Blr. and Elec. Ins. Co.*, Manchester, 1952, vol. 1, page 33.

‖ *Trans. A.S.M.E.*, vol. 60, page 35 (1938); and vol. 73, page 859 (1951).

* *Chem. Ind.*, 1953, page 360.

† *Chem. Ind.*, 1952, page 1040.

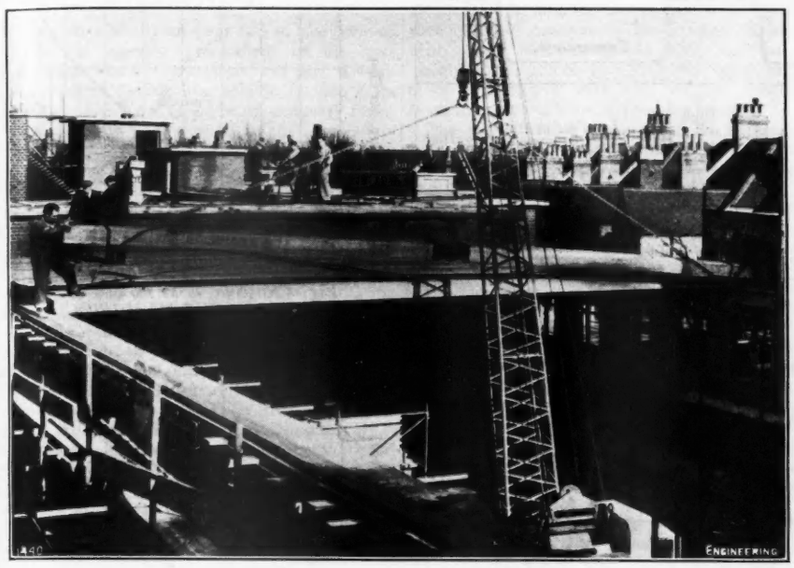
‡ *Amer. Rly. Eng. Soc., Bull.* 490 (1950).

§ *Trans. A.S.M.E.*, vol. 70, page 253 (1948).

* Although theoretically a very low initial $(OH)^-$ concentration in a seam might in time reach a dangerous level by evaporative leakage, this postulates that geometrical conditions under which there is no exchange of liquid between the seam and the body of the boiler water other than the entry into the seam of sufficient liquid to compensate for loss by leakage. If free mixing takes place between the water in the seam and that in the body of the boiler, the concentration process must start afresh. During the long period needed to reach the dangerous level when the initial concentration is low, this free mixing is likely to occur from time to time. Thus if the $(OH)^-$ concentration in the body of the boiler water is kept low, the danger of cracking is small—even though the chance of other types of corrosion becomes enhanced.

LONG-SPAN HOLLOW ROOF SLABS.

CONCRETE, LTD., HOUNSLOW.



LONG-SPAN HOLLOW ROOF SLABS.

WHAT are believed to be the longest hollow roof slabs ever to be erected have been used in the construction of the gymnasium roof at Chiswick Polytechnic, Bath-road, London, W.4. The clear span of the roof is 40 ft. 9 in. and the span-to-depth ratio of the slabs is about 50 to 1. The slabs are of the type that is known by the trade name of "Bison," and are made and erected by Concrete, Limited, Green-land, Hounslow, Middlesex. The slabs are hollow pre-cast concrete beams, either reinforced by bars or prestressed by high-tensile steel wires, and an article describing their manufacture, and the regular testing to which sample beams are subjected by the makers, has already appeared in ENGINEERING, vol. 174, page 154 (1952). It will suffice to say here that the slabs, which are 14 in. wide and are placed side by side and grouted together to form the roof or floor, are cast hollow using a pneumatic core. This ingenious device has been designed to form a cavity without abrupt changes of section (which might prove to be sources of weakness). It has metal plates at the top and bottom; when inflated, the core is quite rigid, thus ensuring an accurate location of the cavity for the full length of the slabs. When the concrete has matured sufficiently, the core is deflated and withdrawn, the ends of the slabs then being sealed with *in situ* concrete.

At Chiswick, as can be seen from the accompanying illustration, the slabs were slung into position by a mobile crane and, despite extremely difficult site access, the entire roof area of 330 sq. yd. was covered in the course of one working week. The units used for this roof are 42 ft. 4 in. long to cover the clear span of 40 ft. 9 in., and are 8½ in. deep at the ends increasing to 10½ in. at the middle. The cavity is 9½ in. wide throughout (giving 2¼-in. walls for each slab) and varies in depth from 5½ in. at the ends to 6½ in. at the middle. The reinforcement consists of 14 high-tensile wires, each of 0·2-in. diameter, in four groups of three wires at the bottom, and with the remaining two wires above the neutral axis of the slab. The overall weight of the units is 80 lb. per foot run; over and above this, they have been designed to carry finishes weighing 28 lb. per square foot and an incidental live loading of 25 lb. per square foot, this latter figure being sufficient to provide for possible external roof loading and a considerable number of hangers for the gymnasium below. Sample beams tested at the yards showed that units were able to carry twice the superimposed load without any sign of cracking, and that, under the designed live load of 25 lb. per square foot, the central deflection was 0·435 in., or less than one eleven-hundredth part of the span.

The architects for the work were Messrs. Dalgliesh and Pullen, FF.R.I.B.A., 17, Fitzhardinge-street, Portman-square, London, W.1, working in conjunction with Mr. C. G. Stillman, F.R.I.B.A., architect to the Middlesex County Council. The builders were F. Troy and Company, Limited, 131, Great Suffolk-street, London, S.E.1.

LAUNCHES AND TRIAL TRIPS.

M.S. "MIDDLESEX."—Single-screw refrigerated-cargo liner, built by Alexander Stephen & Sons, Ltd., Linthouse, Glasgow, for the Federal Steam Navigation Co., Ltd., London, E.C.3. Eighth vessel of a series constructed for these owners. Main dimensions: 469 ft. 6 in. by 64 ft. 6 in. by 42 ft.; gross tonnage, 8,230; deadweight capacity, 10,300 tons on a draught of 27 ft. 4 in. Two ten-cylinder Sulzer Diesel engines, designed for burning boiler fuel, and together developing 9,000 s.h.p. at 225 r.p.m. One engine constructed by Sulzer Brothers, Winterthur, Switzerland, and the other by Stephen & Sons. Both engines attached to one shaft through British Thomson-Houston magnetic couplings and gearing supplied by the Power Plant Co., Ltd., West Drayton, Middlesex. Speed, 16 knots. Trial trip, April 9.

S.S. "ALCYON."—Single-screw cargo vessel, built and engined by Smith's Dock Co., Ltd., South Bank-on-Tees, for A/S Bruusgaard and A/S Acadia, Drammen, Norway. Main dimensions: 300 ft. between perpendiculars by 46 ft. 7 in. by 28 ft. 3 in. to shelter deck; deadweight capacity, 3,550 tons on a draught of 19 ft. Triple-expansion steam engine and two Scotch boilers, developing 1,550 i.h.p. in service. Speed, about 12 knots. Launch, April 15.

S.S. "TOSCA."—Single-screw cargo vessel, built by Bartram & Sons, Ltd., Sunderland, for Rederi A/B Soya, Stockholm. Main dimensions: 445 ft. between perpendiculars by 62 ft. by 40 ft. 2 in.; deadweight capacity, about 10,350 tons on a draught of 27 ft. Triple-expansion reheat reciprocating steam engine, developing 3,900 i.h.p. in service, and three multitubular oil-burning boilers, constructed by the North Eastern Marine Engineering Co. (1938), Ltd., Sunderland. Speed, about 12¼ knots in service. Trial trip, April 23.

M.S. "SILVERBROOK."—Single-screw oil tanker, built by Smith's Dock Co., Ltd., South Bank-on-Tees, for the Silver Line, Ltd., London, E.C.2. Main dimensions: 528 ft. 10 in. overall by 69 ft. 6 in. by 38 ft.; deadweight capacity, 16,630 tons on a draught of 29 ft. 10½ in. Hawthorn-Doxford five-cylinder two-stroke opposed-piston oil engine, developing 5,000 b.h.p. at 110 r.p.m. in service, constructed by R. and W. Hawthorn, Leslie & Co., Ltd., Newcastle-upon-Tyne. Service speed, 13 knots. Trial trip, April 27.

CREEP TESTS ON NIMONIC ALLOYS UNDER VARYING STRESS AND TEMPERATURE.*

By D. C. HERBERT, B.Sc. (Eng), G.I.Mech.E., and D. J. Armstrong, G.I.Mech.E.

TURBINES have frequently to operate at specified levels of power for certain periods, with correspondingly different conditions of stress and temperature, the cycle being repeated daily in some cases. In the design of gas-turbine blades, this factor may be important, and it is essential that creep tests be carried out to give a quantitative picture of the behaviour of a blade material. For this purpose, equipment has been built at the National Physical Laboratory, and a few creep tests have been conducted on two typical gas-turbine blade materials under cyclic changes of stress and temperature.

Little information has been published regarding the effect of changes of stress or temperature on creep rates and fracture characteristics. In general, marked changes in behaviour would not be expected in normal high-temperature engineering materials as a result of "rest periods" during which either the load or temperature had been appreciably reduced. This statement is certainly substantiated by 30 years' experience of creep testing at the N.P.L. There have been occasions when creep test-pieces have been cooled to room temperature as a result of furnace or power failure, or when creep tests have been restarted some time after complete stoppage, and in every instance the creep rate (after an initial recovery period) has settled down to a value similar to that obtaining before the interruption. This is not to say that minor changes of creep rate—as a result of creep recovery for instance—may not occur, nor, in some of the more complex materials, that a rapid cooling of the test-piece may not result in some minor structural change; but the quantitative results would be expected to be within the normally accepted rather wide limits of scatter associated with creep-rate data.

In spite of the foregoing generalisations, peculiar effects have been reported by some workers. In particular, Brophy and Furman† have stated that a cyclic temperature change could lead to much greater creep rates and to increased final elongations. Others have reported no appreciable change in creep rate. The effect of temperature cycles is by no means clear from these reports, however, as oscillating temperatures of both large and small amplitude have been used and some workers have merely cooled to room temperature and reheated. The effect of combined changes of stress and of temperature was studied by Foley‡ who completely unloaded and cooled his specimens periodically; the effect of this was to produce a somewhat higher creep rate.

Bailey§ and also Johnson,‖ have considered the problem of "peak load" increases of stress and temperature, such as occur in electricity generating stations. These changes are generally small, however, and, for design purposes, their effects can be combined into an "equivalent temperature" change at constant stress, the combined effect being

* Communication from the National Physical Laboratory.

† "The Cyclic Temperature Acceleration of Strain in Heat-Resisting Alloys," by G. R. Brophy and D. E. Furman. *Trans. A.S.M.*, vol. 30, pages 1115 to 1138 (1942).

‡ "Interpretation of Creep and Stress-Rupture Data," by F. B. Foley. *Metal Progress*, vol. 51, pages 951 to 958 (1947).

§ "Steam Piping for High Pressures and High Temperatures," *Proc. I. Mech. E.*, vol. 164, page 324 (1951), and "Creep Relationships and Their Application to Parts Under Pressure," *ibid.*, vol. 164, page 425 (1951); both by R. W. Bailey.

‖ "The Effect of Fluctuations of Stress and Temperature on the Creep Properties of Steels Typical of those used in Power Plant," by A. E. Johnson. *Nat. Phys. Lab. Paper* No. H.T. 20/52 (1952). See also "Creep Properties of Steels for Power Plants," by A. E. Johnson and N. F. Frost, ENGINEERING, pages 25 and 58, *ante* (Part I) and page 249, *ante* (Part II).

then determined by an averaging process over the service life; these changes are generally fairly small and, when averaged over long periods, amount to 1 or 2 deg. C.

Kennedy* has recently published the results of creep tests on lead and a lead alloy, in which the stress was removed for rest periods at regular intervals; his interpretation of these tests, based on the very simple Andrade model, leads him to the conclusion that there should generally be a small increase in primary creep on each re-application of the load, and that cases in which no increase is observed would be unusual limiting cases. This is for materials under conditions where no appreciable creep recovery takes place on unloading. A short summary of work in this field was made by G. V. Smith† who gives more detailed information.

The work mentioned, although related to a variety of materials, including ferritic and austenitic steels, is not very helpful in assessing the effect of a service life during which both stress and temperature may have two or three levels of operation for appreciable periods. The work to be described below was carried out using a cycle in which two levels of operation were used, the stress at the lower level being 90 per cent. of that at the higher level, and the temperatures 780 and 640 deg. C., respectively.

The materials tested were samples of Nimonic 80A and Nimonic 90. The Nimonic 80A was in the form of a bar, $\frac{3}{4}$ in. in diameter, heated 8 hours at 1,080 deg. C., air-cooled, followed by 16 hours at 700 deg. C. and air-cooled. The composition (N.P.L. analysis) was: C, 0·082; Si, 0·33; Cr, 20·1; Ti, 2·48; Al, 0·56; Fe, 0·11; Ni, 76·3 per cent.

The Nimonic 90 was in the form of a $\frac{3}{4}$-in. diameter bar, heated 8 hours at 1,080 deg. C., air-cooled, followed by 16 hours at 700 deg. C. and air-cooled. The composition (maker's analysis) was: C, 0·07; Si, 0·48; Mn, 0·13; Fe, 0·38; Cr, 19·40; Ti, 2·56; Al, 1·54; Cu, 0·10; Co, 19·10; Ni, balance.

The tests were carried out in N.P.L.-pattern 2-ton tensile creep machines, the stress being applied to the specimens by hanging weights on the end of a lever, and creep strain being measured by an extensometer attached by clamped points on a gauge length of 2 in., using an optical lever for magnification. Changes of stress were made by removing part of the weight on the lever by hydraulic means, an electric motor and oil pump providing the necessary links with the controlling time switch. The temperature was controlled by a direct-deflection thermocouple controller, a proportioning device being added to give closer temperature control. Changes of temperature were effected by switching in extra resistance into the thermocouple circuit in order to change the control point of the controller.

Both materials were tested using a cycle as shown schematically in Fig. 1, herewith, repeated every 24 hours, in which the high-level conditions were 780 deg. C. and 10·8 tons per square inch for 6 hours, and the low-level conditions 640 deg. C. and 9·7 tons per square inch for 18 hours. Comparative tests were also made under constant conditions of 780 deg. C. and 10·8 tons per square inch.

Nimonic 90 was also tested, using a higher stress of 15 tons per square inch, reduced to 13·5 tons per square inch for the low level, the temperatures and time intervals being as before and a constant-condition test again being made for comparison. All tests were continued to fracture, observations of the strain being recorded at intervals, which were frequent except when operating at the low levels. Creep recovery was minimised by cooling the specimen before reducing the load in each cycle.

TEST RESULTS.

The results of all tests are given in numerical form in the Table, and creep curves are shown plotted in Figs. 2 to 4, herewith. In all cases, times at the low levels have been considered as rest periods and the times given are, therefore, times

* "The Creep of Metals Under Interrupted Stressing," by A. J. Kennedy. *Proc. Roy. Soc.* A, vol. 213, pages 492 to 506 (1952).

† *Properties of Metals at Elevated Temperatures*, by G. V. Smith. McGraw-Hill Publishing Company (1950).

CREEP TESTS ON NIMONIC ALLOYS.

Fig. 1. TEST CYCLE (SCHEMATIC).

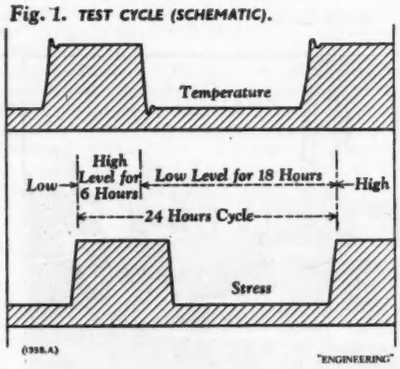


Fig. 2. NIMONIC 80A AT 780 DEG. C. 10·8 TONS PER SQ. INCH.

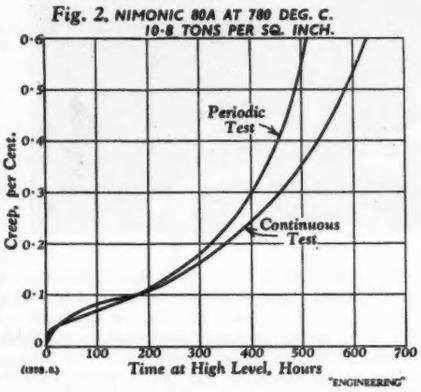


Fig. 3. NIMONIC 90 AT 780 DEG. C. 10·8 TONS PER SQ. INCH.

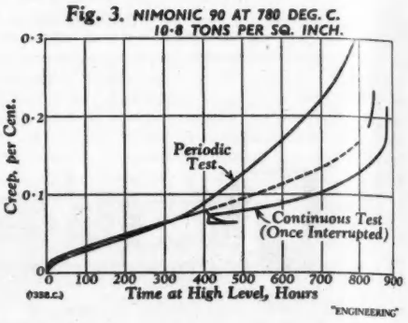
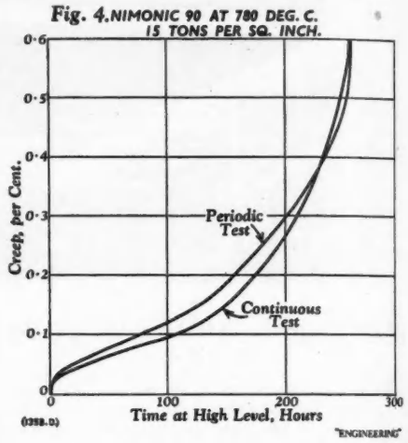


Fig. 4. NIMONIC 90 AT 780 DEG. C. 15 TONS PER SQ. INCH.



at high level only. This method of presentation is amply justified by the results of the tests, as, in every case, until the tertiary stage is reached, there is very little difference between the values of creep strain at specified times for the continuous as compared with the periodic tests. This is most easily seen by reference to the plotted curves, for, neglecting the complication introduced by completely shutting down one of the tests in Fig. 3, it seems reasonable to assume that any differences are due to experimental errors associated with the periodic testing.

Examination of the tertiary part of the curves shows that creep rates were greater in the periodic tests, but final fracture occurred at about the same times in both periodic and continuous tests and with similar final elongations (see Table), the curves in some cases crossing each other twice. In Fig. 3, in which the continuous test was shut down and then continued to fracture, the complicating effect of creep recovery may be observed, being almost completely absent when the temperature was dropped to 640 deg. C. at the low-level tests in periodic testing. The complete recovery curve is shown up to the point where the furnace was switched off, and the shortening of the test-piece which resulted has been taken into account when fitting the new curve obtained on reloading. A possible course has been indicated by a broken line, which shows where the curve might have been had no interruption taken place. The causes contributing to the decrease in creep rate over the remainder of the test are not at all clear; it seems likely that the main cause was the cooling down after a period of creep recovery at test temperature, as recovery alone would be unlikely to be followed, on reloading, by a rate of primary creep less than either the recovery rate or the original primary creep rate, as was displayed by this specimen. It is not thought that the lower creep rate was due to experimental errors, as the tests in question were well up to normal standard. If Kennedy's explanation, referred to above, were valid, an increased creep rate should have been observed unless recovery restored the material to its original condition; the decreased rate could not be explained by his arguments.

It is clear that the effect of cycles described here could be assessed approximately by considering solely times at the high-level conditions, as times at the low level played only a small part and could be treated as rest periods. However, it does not seem justifiable to ignore altogether the periodic nature of the loading, as there was some tendency for the creep strain to be greater than would have been the case were no rest periods to occur.

RESULTS OF TESTS.

Test Material and N.P.L. Test Mark.	Loading Cycle. Tons per sq. in.	Hours.	Tons per sq. in.	Hours.	Total Cycle, Hours.	Creep at Following Times in Hours, per cent. 20	50	100	200	500	Fracture time, Hours.	Final Elongation per cent. on $4\sqrt{\text{Area}}$.
Nimonic 80A. Temperature cycle, 780 deg. C. and 640 deg. C.												
SMW 14 C1	10·8	6	9·7	18	24	0·03$_6$	0·05	0·07	0·12	0·55	620	3
SMW 16 C1	10·8	24	—	—	24	0·03	0·05$_8$	0·08	0·10$_8$	0·35	750	4$_2$
Nimonic 90. Temperature cycle, 780 deg. C. and 640 deg. C.												
TPA 8 C2 ..	10·8	6	9·7	18	24	0·01	0·01$_2$	0·02$_2$	0·04$_2$	0·13	841	1$_2$
TPA 7 C2 ..	10·8	24	—	—	24	0·01$_2$	0·02$_2$	0·03$_2$	0·04$_2$	0·10	879	1
Nimonic 90. Temperature cycle, 780 deg. C. and 640 deg. C.												
TPA 7 C1 ..	15	6	13·5	18	24	0·04$_2$	0·07	0·12	0·30	—	257	1$_2$
TPA 7 C3 ..	15	24	—	—	24	0·04	0·06	0·09$_2$	0·26	—	263	1$_2$

USERS' AND FOUNDERS' REQUIREMENTS IN STEEL CASTINGS.

WE reported briefly on page 531 of the issue of April 24 the opening proceedings of the first "Customer-Founder Convention" of the British Steel Founders' Association, held in London from April 15 to 17. We give below, in summary form, some of the main points raised in the five papers presented at the conference.

APPLICATION OF STEEL CASTINGS.

The first paper was by Mr. Frank Rowe, B.Sc., managing director of K. & L. Steelfounders and Engineers Ltd., and dealt with "Steel Castings and their Application." Mr. Rowe stated that one of the most valuable properties of a steel casting—and one which was often overlooked—was its freedom from directional properties. It was apt to be forgotten that the mechanical properties associated with rolled or forged steel were those which the material possessed along the direction of the flow lines only. When tested at right angles to the flow lines, the toughness and ductility, were usually very low compared with those obtaining in every direction in a steel casting. Thus a sound, properly heat-treated, steel casting was the strongest and toughest form in which steel could be produced. Unfortunately, to realise to the maximum the whole of the possibilities of a steel casting required great skill, both on the part of the designer and that of the founder. There were three major factors which made the material more difficult to cast than any other. The first of these was the large amount of shrinkage which took place while the liquid steel was cooling; the second was the low strength and ductility of cast steel at temperatures immediately below the freezing point, around 1,480 deg. C.; and the third was the high melting point, and, therefore, high casting temperature—1,540 deg. to 1,600 deg. C.—of steel.

High liquid shrinkage had to be compensated for by large feeding heads. The average yield of a good steel foundry was 50 per cent. That meant that 100 tons of molten steel were needed to produce 50 tons of castings. The other 50 tons went largely in feeding heads. A steelfounder had to try to arrange his moulding and casting methods so that the casting solidified progressively and evenly from the bottom to the top so as to avoid hot spots which caused shrinkage cavities. It was often possible to change the thickness of metal in a steel casting gradually to avoid abrupt changes of section and sharp corners, which were a prevalent source of hot tears. Much progress had been accomplished in the last 10 or 15 years and the advent of industrial radiography had enabled great strides to be made in foundry techniques, both with properly and with improperly designed castings.

CUSTOMERS' EXPERIENCES.

Two papers on "Customers' Experience with Steel Castings" were presented and discussed. Mr. R. A. Riddles, C.B.E., M.I.Mech.E., M.I.Loco.E., member of the Railway Executive, the author of the first of these papers, stated that British Railways were perhaps fortunate in having one steel foundry in connection with which there had always had to be close contact between designer and founder. Most castings were subjected to some form of machining operation before they could be used in an assembly and this machining was often carried out with the aid of jigs and fixtures. It was necessary that the founders should be made aware of the type of jig or fixture used, and of the location of datum points or faces used to control all machining operations. Large and complicated castings, such as frame stretchers, bogie centre castings, cylinders, and motion brackets, should all be set up and identified before dispatch to prove that all faces marked on the drawing for machining had sufficient allowance for the purpose, and also that the castings had not become distorted either in cooling in the moulds or during annealing. There were times when a casting containing defects could be salvaged by the discreet use of welding, but there were other times when such practices should not be applied. The question of cost was of importance. A cast-iron axlebox cost 3*l.* 2*s.* 9*d.*, a cast-steel one of similar design, 6*l.* 7*s.* 0*d.*, and a welded box 5*l.* 5*s.* 0*d.* Fabrication by welding was now quite a formidable rival to steel castings in the railway-engineering field. Steel founders should look, and ask, for design simplification where this could make castings more competitive with the welded component from the point of view of cost and weight.

The second paper was by Mr. A. C. Annis, of the Metropolitan-Vickers Electrical Company, Limited, and the author stated that his engineering and metallurgical colleagues had expressed the views that greater emphasis was required on technical control in the steel foundries, from raw material to final castings, and that the processes should be controlled by instrumentation and recording as far as possible. It was, moreover, considered that all faulty castings should be investigated by a qualified metallurgical staff and that appropriate instructions should be issued to avoid repeated faults, regardless of personnel changes at a future date. Emphasis was also laid on the desirability of pursuing to the utmost the visual inspection of the parent metal at the earliest possible stage, as careful visual examination still provided one of the best means for the detection of external defects. It was stressed that there was no question in the minds of the designers that, following the issue of final drawings by the purchasers, discussion of any foundry problems that could be eliminated by a change should take place. It was added in parenthesis, however, that when this had been done and the designs had been cast unchanged for several years with satisfactory results, there had yet been periods of deterioration in regard to which no satisfactory explanation had been offered by the steel founders. The defects complained of were minor porosities, small surface cracks, numerous areas of "bad metal," extensive cracks of considerable depth, and large "scabs" which became dislodged in service. The final contention was that, frequently, steel founders' repairs consisted of bad welds involving insufficient excavation of the defects, cold welds and the use of wrong or damp electrodes. On this account, it had become necessary for the client's metallurgist to supervise repairs at the steel founders' works.

QUALITY CONTROL AND INSPECTION.

Dr. J. R. Rait, of Hadfields Ltd., presented a paper entitled "Quality Control and Inspection as Part of the Manufacturing Process of Steel Castings." The author stated that quality control could be divided into three main sections, namely, the control of raw materials, the control of production methods and the control, or inspection, of the casting produced. It was becoming general practice in modern steel foundries to specify a production procedure, or method, for each foundry operation and, in modern organisations, the function of establishing and recording standard methods was usually vested in a foundry methods section. The positioning and dimensions of heads, ingates and chills and the use of such devices as insulating pads or exothermic moulding materials were specified by the section. These features were not, as had often been the case in the past, left to the discretion of the individual moulder. The importance of quality control in the production of liquid steel had been recognised, of course, for many years, and certain of the routine tests applied during processing were of relatively long standing.

As the mechanical properties of a casting, and its consequent ability to withstand the loads encountered in service, were dependent on the correctness of the heat treatments applied, it was apparent that close metallurgical control was necessary at all stages of this manufacturing operation. Providing that weld repair was carried out under controlled conditions and close supervision, the serviceability of a casting dealt with in this manner, in general, would not be impaired. The non-destructive testing of steel castings held an important place in inspection operations and the principal methods employed included magnetic-crack detection techniques, acid etching or pickling, radiography, and ultrasonic flaw-detection processes.

RESEARCH AND THE CUSTOMER.

Mr. J. F. B. Jackson, director of the British Steel Castings Research Association, dealt with "Research as it Affects the Customer." He drew attention to three major researches now under way under the auspices of the Association. These concerned the mechanism of freezing of steel in sand moulds, the interaction between molten steel and silica moulding sands, and the resistance offered by various moulding materials to the solid contraction of steel castings when still in their moulds in the foundry. The research on the mechanism of freezing led directly towards the adoption of optimum form and dimension feeder heads, having due regard not only to the avoidance of shrinkage cavities but also to metal economy and to the physical properties of the casting itself. As a result of work on the elucidation of the causes of sand penetration by molten steel, it had been found possible to produce, in the laboratory, precisely the same phenomenon as that which occurred in industrial practice. This meant that investigators could proceed to examine the "burning-on" process under conditions which were quantitatively varied and controlled. It was likely that, within the foreseeable future, the relative importance of the various factors which determined whether or not metal penetration of the mould face occurred, and burnt-on sand resulted, would be established.

The third major research, namely, that on the prevention of hot tears, or the local rupturing of steel castings while still at high temperatures and still in their moulds, was of considerable consequence to producers and also to users of steel castings. A test apparatus had been developed to assess quantitatively the resistance of various classes of mould refractory and bonding agent to the contraction of molten steel. In this apparatus a test casting was moulded in such a manner that its contraction after solidification was hindered by a block of the mould materials under test, the force exerted on the test casting by the moulding materials being indicated by a calibrated beam. The casting itself, of course, was examined for the incidence of hot tears after it had been removed from the mould. The results obtained gave the steelfounder direct assistance in selecting, for castings that were prone for design reasons to hot tears, those moulding materials which would minimise the occurrence of such effects.

In the course of his concluding remarks, the chairman of the Convention, Mr. T. H. Summerson, made reference to the practice adopted, in some industries, of establishing a committee for more or less continuous collaboration between the works manager, engineer, metallurgist, chief draughtsman, chief patternmaker, purchasing agent and steelfounder. It was to be hoped that this practice would be more widely adopted by users of steel castings. In conclusion, Mr. Summerson stated that the Convention had been so successful that it might well be that a series of these meetings would be held in the principal industrial centres.

DEPARTMENTAL COMMITTEE ON FLOOD CONTROL.—The Home Secretary has announced that invitations to serve under Lord Waverley on the Departmental Committee on Flood Control have been accepted by Mr. R. D. Gwyther, M.I.C.E., senior partner in the firm of Coode and Partners, chartered civil engineers; Mr. G. M. B. Dobson, Reader in Meteorology in the University of Oxford; and Sir Miles Thomas, chairman of B.O.A.C. These three, together with the chairman and the ten names already announced, as reported in ENGINEERING, page 404, *ante*, constitute the full membership of the committee.

COMBATING THE DEATH-WATCH BEETLE.—At the suggestion of Dr. Hugh Hay, a London radiologist, it is proposed to investigate the use of X-rays and other physical methods to combat the death-watch beetle in Nelson's flagship, H.M.S. Victory. Although satisfaction is expressed at the measures at present being adopted, due to the complexity of the problem it is felt that these new methods of attack are well worth further exploration. To examine the problem, a committee has been appointed that includes, besides Dr. Hay and others, Dr. R. C. Fisher and Mr. E. C. Harris of the Forest Products Research Laboratory, and Dr. H. J. Plenderleith of the British Museum.

BOOKS RECEIVED.

University of Illinois Engineering Experiment Station. Circular Series No. 65. *An Electric Recording Water Meter.* By JOHN K. TUTHILL. The Director, Engineering Experiment Station, University of Illinois, Urbana, Illinois, U.S.A. [Price 20 cents.]

University of Illinois Engineering Experiment Station. Bulletin Series No. 403. *Comparative Performances of Two Warm-Air Perimeter Systems and Three Convection Systems.* By MORRIS E. CHILDS and others. [Price 60 cents.] No. 404. *Gradually Varied Flow in Uniform Channels on Mild Slopes.* By MING LEE, PROFESSOR HAROLD E. BABBITT and E. ROBERT BAUMANN. [Price 1 dol.] No. 405. *Studies of Slab and Beam Highway Bridges. Part IV. Full-Scale Tests of Channel Shear Connectors and Composite T-Beams.* By PROFESSOR IVAN M. VIEST and others. [Price 1 dol.] The Director, Engineering Experiment Station, Urbana, Illinois, U.S.A.

The Loop Film. By R. A. N. SMITH. Current Affairs, Limited, 174, Brompton-road, London, S.W.3. [Price 7*s.* 6*d.*]

United States National Bureau of Standards. Circular No. 534. *Hearing Aids.* By EDITH L. R. CORLISS. [Price 15 cents.] No. 536. *Radio-Frequency Power Measurements.* By ROALD A. SCHRACK. [Price 15 cents.] The Superintendent, U.S. Government Printing Office, Washington 25, D.C., U.S.A.

Bewertungszaheen fur Wärmeaustauscher. By H. NOVAK and others. Abhandlungen des Deutschen Kältetechnischen Vereins. No. 7. Verlag C. F. Müller, Karlsruhe, Germany. [Price 5.60 D.M.]

Radio Research. Special Report No. 23. *Characteristics of the Ionosphere, Observed in Great Britain, 1930-1946.* H.M. Stationery Office, Kingsway, London, W.C.2. [Price 1*s.* 6*d.* net.]

Canada. Department of Mines and Technical Surveys. Mines Branch. Technical Paper No. 1. *The Determination of Thorium in Ores by the Column Method.* By R. J. GUEST. [Price 25 cents.] No. 2. *The Constitution of Bone China. Part I. High-Temperature Phase Equilibrium Studies in the System Tricalcium Phosphate-Alumina-Silica.* By P. D. S. ST. PIERRE. [Price 50 cents.] The Director, Department of Mines and Technical Surveys, Mines Branch, Ottawa, Canada.

TRADE PUBLICATIONS.

Rotary Dryers and Coolers.—We have received illustrated booklet No. 9701 from the Sturtevant Engineering Co., Ltd., Southern House, Cannon-street, London, E.C.4, describing their rotary dryers and coolers for ores and powders and washing and drying machines for small parts. The dryers are in sizes from 20 in. to 6 ft. 7 in. diameter, and the coolers will handle 1 to 20 tons of material per hour.

Four-Stroke Stationary Diesel Engines.—Burmeister and Wain, Ltd., Copenhagen, Denmark, have sent us a brochure with illustrations, diagrammatic drawings, and dimensions of their range of Diesel engines for outputs from 10 b.h.p. to 1,015 b.h.p.

Rock-Loading Shovels.—We have received two illustrated pamphlets from Eimco (Great Britain) Ltd., Barras Garth-road, Leeds, 12, describing their "Rocker Shovels," models 12 b and 21, suitable for loading cut coal or rock spoil into tubs. We have also received an illustrated brochure listing other products of the parent company, Eimco Corporation, Salt Lake City, 8, Utah, U.S.A.

Self-Contained Alarm Systems.—Details of their self-contained alarm systems which have been designed to indicate conditions at an unattended substation and to repeat it to a central point are given in a pamphlet received from Standard Telephones & Cables Ltd., 63, Aldwych, London, W.C.2.

Engraving and Nameplates.—The British Engraving and Nameplate Manufacturing Co. (London), Ltd., Benco House, 5, Fitzroy-street, London, W.1, have issued a leaflet illustrating examples of their engraved placards, instruction diagrams, nameplates, etc., available in plastics, metals, ivorine, etc.

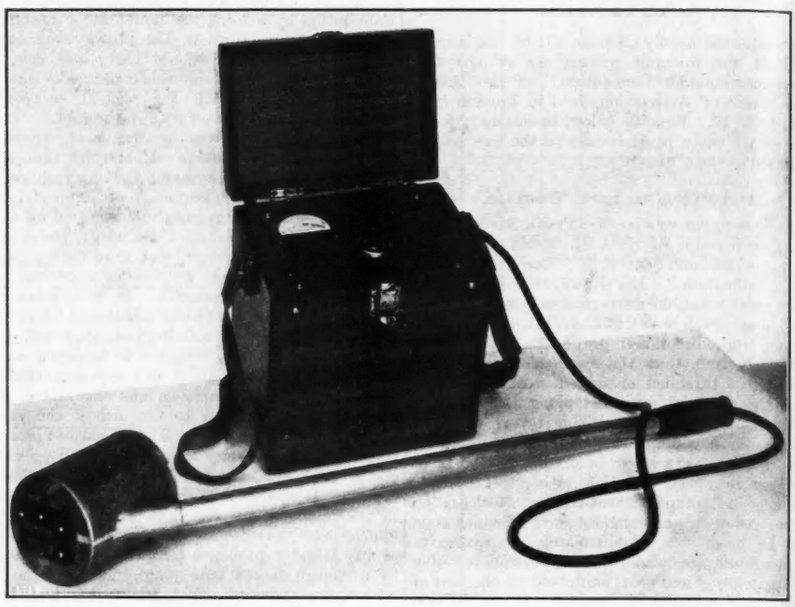
Caliper Thread Gauges.—Tolomit Gauges Ltd., 16, Peterborough-road, London, S.W.6, have sent us an illustrated leaflet describing their adjustable caliper thread gauges.

Copying Lathes.—A copy of the latest catalogue produced by H.E.B. Machine Tools, Ltd., 5-17, Haverstock-hill, Chalk Farm, London, N.W.3, has been received. It describes their high-speed hydraulic copying lathe, full details of which were given in ENGINEERING, vol. 171, page 284 (1951).

Squirrel-Cage Electric Motors.—A pamphlet issued by Lancashire Dynamo and Crypto, Ltd., Trafford Park, Manchester, 17, gives details of the totally-enclosed fan-cooled squirrel-cage motors for voltages up to 600 which they are manufacturing to comply with the standard dimensions of three-phase electric motors proposed by the British Standards Institution.

CHECKING CONCRETE WATER-CEMENT RATIO.

SQUARE GRIP REINFORCEMENT CO. (LONDON), LTD., SUNBURY-ON-THAMES.



CHECKING THE WATER-CEMENT RATIO OF CONCRETE.

THE water-cement ratio is a fundamental factor controlling the strength of concrete. An instrument, the S.G. water-cement "ratiometer," has been developed at the Civil Engineering Laboratories of the Square Grip Reinforcement Company (London), Limited, Sunbury-on-Thames, for checking this ratio while the concrete is still in the mixer. The ratiometer, as shown in the accompanying illustration, comprises two parts, a probing tool for investigating the concrete and an instrument box containing the electrical circuits, control panel and batteries, their total weight being 24 lb. Within the head of the probe is a small vibrating unit which, when totally immersed in the concrete, is used to separate the aggregates thereby bringing the slurry to the surface, the time for which the vibrator has to be immersed depending on the quality of concrete being examined. The water-cement content of the slurry is then determined in terms of its resistance to a current passing between the two electrodes on the bottom face of the probe. In order to approach consistent conditions at the time of observing the resistance, the probe is withdrawn until the bottom face just rests on the surface of the concrete mix.

The instrument is comparative in operation, the readings observed for the inspected concrete being compared with those obtained on sample mixes made from similar aggregates used in the same proportions as in the inspected concrete, but having known water-cement ratios. To assist in making the comparison the control panel is fitted with an ammeter dial that has been divided into three regions marked "too dry," "O.K." and "too wet," and with a rheostat adjustment which is fitted with a pointer that travels over a divided scale numbered in units from 0 to 100; the number indicated by the pointer on the rheostat is termed the code number for the sample of concrete being examined.

When using the instrument as a simple comparator to determine the correctness, or otherwise, of the water-cement ratio of a mix, a standard sample of correct mix is made and, with the probe correctly placed on the surface of the sample, the rheostatic control is adjusted until the quality pointer indicates the centre of the "O.K." region, when the code number is noted. The probe is then transferred to the mix to be examined and, with the code number kept in the correct position, the quality reading is observed as "too dry," "O.K." or "too wet" from which, if necessary, appropriate changes can be made in the mix. In order to use the ratiometer to determine the actual water-cement ratio of a concrete, it is first necessary to prepare a number of samples with different water-cement ratios and to draw up a calibration graph relating the water content to the code number, as measured by the instrument. Then, by measuring the code number of the mix to be examined, its water-cement ratio can be determined by interpolation from the graph.

The instrument has two possible sources of error, both of which, it is claimed, can be overcome by careful use and by calibrating the instrument as it is used and under the conditions in which it is to be used. The first of these two errors is concerned with the varying resistance of the instrument circuit; in particular, the battery. This source of inaccuracy is overcome by regular calibration. The second inaccuracy relates to the precise nature of the factor being measured, particularly the degree to which the separated slurry is truly representative of the water-cement mix. This difficulty is similarly overcome by calibration of the instrument, care being taken to eliminate all possible variables by using identical materials and conditions for calibration as for the concrete mix under test. It is stated by the makers that extensive tests have proved that, if due care and attention are paid to the way in which the instrument is handled, the ratiometer will give readings sufficiently accurate for the site inspection of concrete.

ADEN OIL REFINERY: ERRATUM.—In the article on the Aden Oil Refinery, on page 490, *ante*, we reported information sent to us which incorrectly described the piles as "of a modified Larssen box-type section." These piles have, in fact, been specially designed and rolled for the contract by the Cargo Fleet Iron Company, Limited, Middlesbrough.

"SCIENCE ABSTRACTS" ON INDEX CARDS.—Although requests have from time to time been received for an edition of *Science Abstracts* printed on index cards, it has been felt that the necessarily high subscription rate—40*l.* per annum for Section B (Electrical Engineering)—would be prohibitive. As an alternative, an edition printed on one side only has been available, but it has now been found that the cost of this may be comparable to that of a card edition. The Editor, whose address is the Institution of Electrical Engineers, Victoria-embankment, London, W.C.2, would therefore be glad to hear from anyone who would be willing to subscribe up to the above sum, so that the probable extent of the circulation of a car index edition can be determined.